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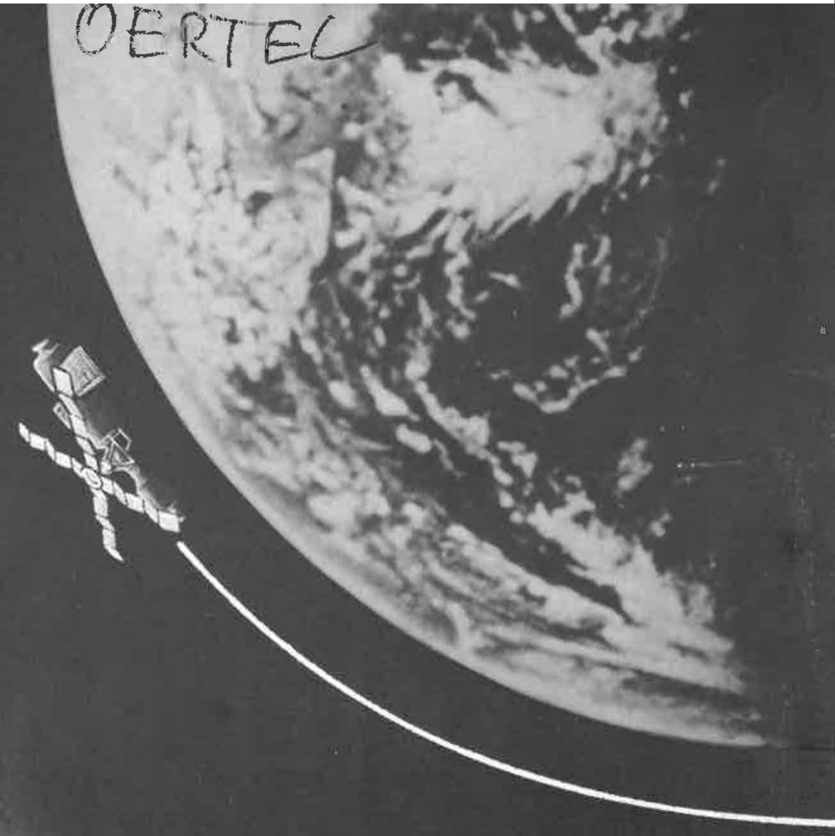

Skylab

-PROGRAM DESCRIPTION-

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

PREFACE

October 1971

This document provides general information concerning NASA'S Skylab Program and is published under a National Aeronautics and Space Administration agreement with the National Science Teachers Association.

This document provides technical background on the Skylab Program for those high school students participating in the Skylab Student Project which is being administered by the National Science Teachers Association.

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I. Introduction

In 1973 three Americans will embark on the first of a series of Earth orbiting missions using Skylab, the first United States vehicle created specifically to enable man to live and work in space for extended periods.

Skylab is a program dedicated to the use of space and its unique environment and vantage point to increase our knowledge and understanding of the Earth's importance to man's well-being and man's influence on Earth's ecology. Skylab will also be a major step in manned space flight. Habitation by the first crew will double our previous man-in-space duration (Gemini VII) and the second visit will redouble that duration. It will, in effect, create a bridge between the development flights of the 60s and the long duration operational space flights of the future.

To accomplish its mission, Skylab will be placed in Earth orbit and will be visited and inhabited by three different crews during an eight-month period. While successfully inhabiting and operating the vehicle for one- and two-month continuous periods, these crews will obtain data in areas pertinent to the man/Earth relationship and to long duration space flight.

Data will be acquired by Skylab primarily through the conduct of "experiments." Four categories of investigation are planned. These are summarized in the following paragraphs.

Physical Science

Increase man's knowledge of the Sun and its importance to Earth's and man's existence. From outside Earth's atmospheric filter, evaluate the lighting, radiation, and particle environment of near-Earth space and the radiations emanating from the Milky Way and remote regions of the Universe.

Biomedical Science

Increase man's knowledge of the biomedical functions of living organisms, human and other, by making observations under conditions different from those on Earth to determine the importance of Earth conditions to these functions.

Earth Applications

Develop techniques for observing Earth phenomena from space in the areas of agriculture, forestry, geology, geography, air and water pollution, land use and meteorology, and the influence man has on these ecological elements.

Space Applications

Develop improved techniques for space operations in the areas of crew habitability, crew/vehicle interrelationships, and space vehicle structure and materials, and evaluate various equipments necessary for successful habitation of the unique environment of space.

II. Unique Features

Skylab is a laboratory and workshop with features that are unattainable on Earth. These features are a sustained zero gravity environment, sustained operation above the Earth's atmosphere, and a sustained broad view of the Earth's surface. The following paragraphs elaborate on each of these features.

Zero Gravity Environment

Like the air we breathe, gravity is a phenomenon we take for granted, only becoming aware of its existence when climbing stairs or mountains, lifting massive objects or dropping delicate objects. In Earth orbit where the Earth's gravitational pull is balanced by the centrifugal force of the orbiting spacecraft, the phenomenon of a force holding things down or pulling them down no longer exists. Objects at rest remain so until disturbed; objects in motion remain in motion until obstructions to that motion are encountered: in clear accordance with Newton's first and second laws.

Desirable and undesirable situations result from weightlessness. The function of operating a switch can send an unrestrained man drifting across the room. Conversely, a man can be motionless in the middle of the room out of reach of a fixed object by which to pull himself "down" to a foothold. Weightlessness can be a boon when movement is desired but a profound nuisance when a man wants to remain in one place to perform a specific function.

Skylab's sustained weightless environment affords us a unique laboratory, useful in expanding our knowledge of the physiology of man and other animals. Observation of various biological processes away from the influence of gravity, and comparison of these observations with similar observations on Earth, can enhance our understanding of these processes.

In earlier studies of the effect of zero gravity on bone mineral content, for example, a similarity was noticed with bone mineral losses evident after prolonged bed rest; however, the rate of change of mineral content was different. In Skylab, with mission durations two to four times the longest duration of previous studies, much more can be learned of this condition and of the role played by Earth's gravity.

Study of the human endocrine system in zero gravity will provide information on the possible role of gravity in that system's control of bodily processes. Similarly, studies of orientation and motion sickness in zero gravity will produce greater knowledge of these mechanisms and of the effect of gravity on them.

Evaluation of the influence of Earth's gravity and its 24-hour day/night cycle, on endocrine, blood circulation, and the nervous systems can be enhanced by observation of life in zero gravity and the 1½ hour day/night cycle of Skylab.

Gravity is also significant in other areas. Liquids display peculiar characteristics in the absence of gravity. When released in free orbit, they are affected only by their surface tension and should form spheres of a perfection unobtainable on Earth, a phenomenon that could have considerable value in casting spherical shapes with high accuracy.

Under the influence of gravity, substances of varying density tend to stratify with the lightest at the top and the heaviest at the bottom. In liquids, very slight differences in density will result in stratification. Without gravity, densities as far apart as liquid metals and gases will not stratify, consequently foamed formations of dense materials could be developed that would produce strength and weight combinations never before encountered.

Many organic molecules pick up small electric charges when placed in slightly acid or alkaline solutions and will move through these solutions when an electric field is applied; different molecules moving at different speeds. This phenomenon is known as electrophoresis. The characteristics of electrophoresis could be exploited in zero gravity where the influence of Earth's gravity on molecules of differing densities is missing. The ability to separate different molecules more precisely could facilitate the preparation of organic materials of uniquely high purity. These materials could have valuable roles in medicine and biological research.

Vaccine development could also benefit from zero gravity research where the suppression of sedimentation and stratification of the culture in which cells under study are suspended could produce cell nutrition and growth phenomena of profound benefit in vaccine production.

Operation Above the Earth's Atmosphere

The air we breathe, the source of our life supporting oxygen, is also a highly protective insulating blanket around the Earth. The Earth's atmosphere protects us by absorbing harmful radiation from the Sun, by diffusing sunlight and by causing all but the largest of meteorite particles to burn up before contacting the Earth's surface. This protection, however, is a hindrance to observation of space phenomena outside the atmosphere. Transmitting only visible light and longer wavelength emissions, the atmosphere filters other wavelengths, in particular the ultraviolet and X-ray portions of the spectrum. In addition, the diffusion of visible light severely limits the clarity of space observations and the daytime scattering of the light masks all but the brightest solar emissions.

Operating at an altitude of 235 nautical miles (270 statute miles or 435 kilometers), Skylab is unhampered by the atmospheric protective layer. At this altitude it is in an "atmosphere" so tenuous that its atoms and molecules are yards apart rather than millionths of an inch apart. This atmosphere affords a level of visibility completely impossible on the surface of the Earth. Astronomical observations in all spectral frequencies can be made, particularly in the X-ray region. Analysis of the radiation and sampling of the particle environment, outside the atmosphere, will be possible, and will include a micrometeoroid impact experiment to provide detailed information on the quantities and composition of these bodies in near-Earth space.

The Broad View of the Earth's Surface

Skylab, with its sophisticated equipment, the observational capability of the crew, and the area of Earth over which it will fly, offers an Earth observation capability never before achieved by a United States manned spacecraft. During the eight-month mission period, Skylab will fly over the contiguous United States, much of Europe, all of Africa, Australia, China, almost all of South America, and the oceans between these areas (Fig. 1). In traversing this area (about 75 percent of the Earth's surface), Skylab will pass over each point once every five days so that, viewing conditions permitting, timebased variations on Earth can be observed.

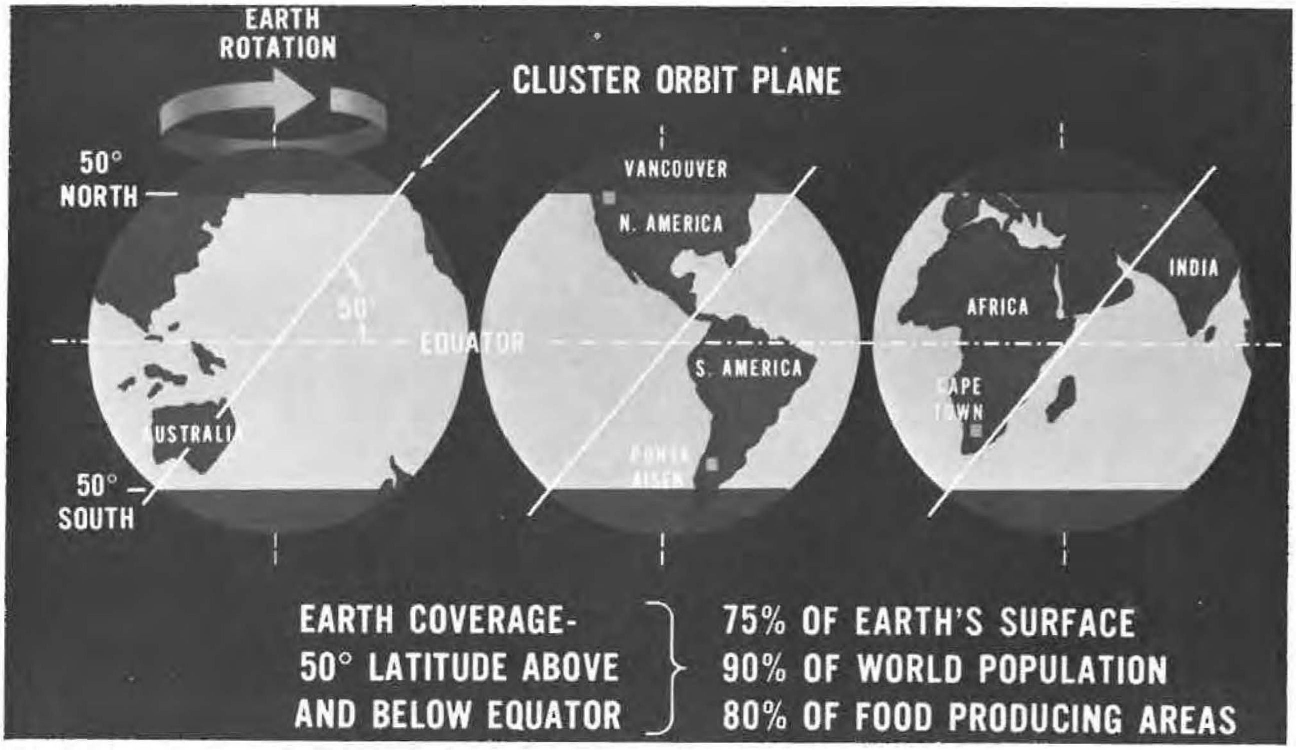


Fig. 1 Earth Coverage

With this excellent Earth view, data can be obtained applicable to mankind's most pressing problems such as weather, crop deterioration, pollution of air and water, flooding and erosion, and the depletion of mineral resources. Entire regional systems such as mountain ranges, river basins, and crop production areas can be observed and analyzed in conjunction with comprehensive ground-based and airborne observations. Studies of the weather over a given region and of the related water distribution could be made within the period of a single mission. By extending the length of the study to the total span of the three Skylab missions (eight months), the effect of the observed water distribution on vegetation in the region could be observed.

From the perspective of the Skylab orbit, it also is possible to relate urban development to geographic features and to derive guidance for future urban development. The relationship of atmospheric pollution to urban development, geographical features, and meteorological phenomena might also be determined.

III. Missions, Vehicles, and Systems

Missions

The Skylab vehicle will operate in space for approximately eight months during which time there will be three manned missions and two periods of unmanned operation (Fig. 2). The first manned mission will begin with two launches from the Kennedy Space Center's Launch Complex 39. The first launch, which is unmanned, will use a two-stage Saturn V booster. Its payload will be Skylab which consists of the Orbital Workshop, the Airlock Module, the Multiple Docking Adapter, the Apollo Telescope Mount, and an Instrument Unit (Fig. 3). A shroud will cover the payload during ascent to orbit.

Skylab will be inserted into a near-circular orbit at an altitude of 235 nautical miles with a nominal orbit inclination of 50 degrees to the Earth's equator (Fig. 1). During the first 7½ hours of flight the following sequence will occur (Fig. 4):

- Jettison of the Payload Shroud;
- Rotation of the Apollo Telescope Mount (ATM) 90 degrees to its operating position;
- Extension of the ATM solar arrays;
- Rotation of the vehicle until the ATM solar arrays point at the Sun;
- Extension of the workshop (OWS) solar arrays;
- Pressurization of the habitable areas to 5 psia.

The second launch will occur the day following the Skylab launch, and will use a Saturn IB to boost the Command and Service Module (CSM) (Fig. 5) and its crew of three astronauts into an interim elliptical orbit with a perigee (low point) 81 nautical miles above Earth and an apogee (high point) of 120 nautical miles. Using the Service Module propulsion system the CSM will transfer from the interim orbit to the Skylab orbit and will rendezvous with Skylab and dock to the axial port of the Multiple Docking Adapter, thus completing the cluster (Fig. 6). The crew will enter and activate Skylab for habitation. The CSM will be "powered down" to the maximum extent, with only essential elements of the communications, instrumentation, and thermal control systems still operating.

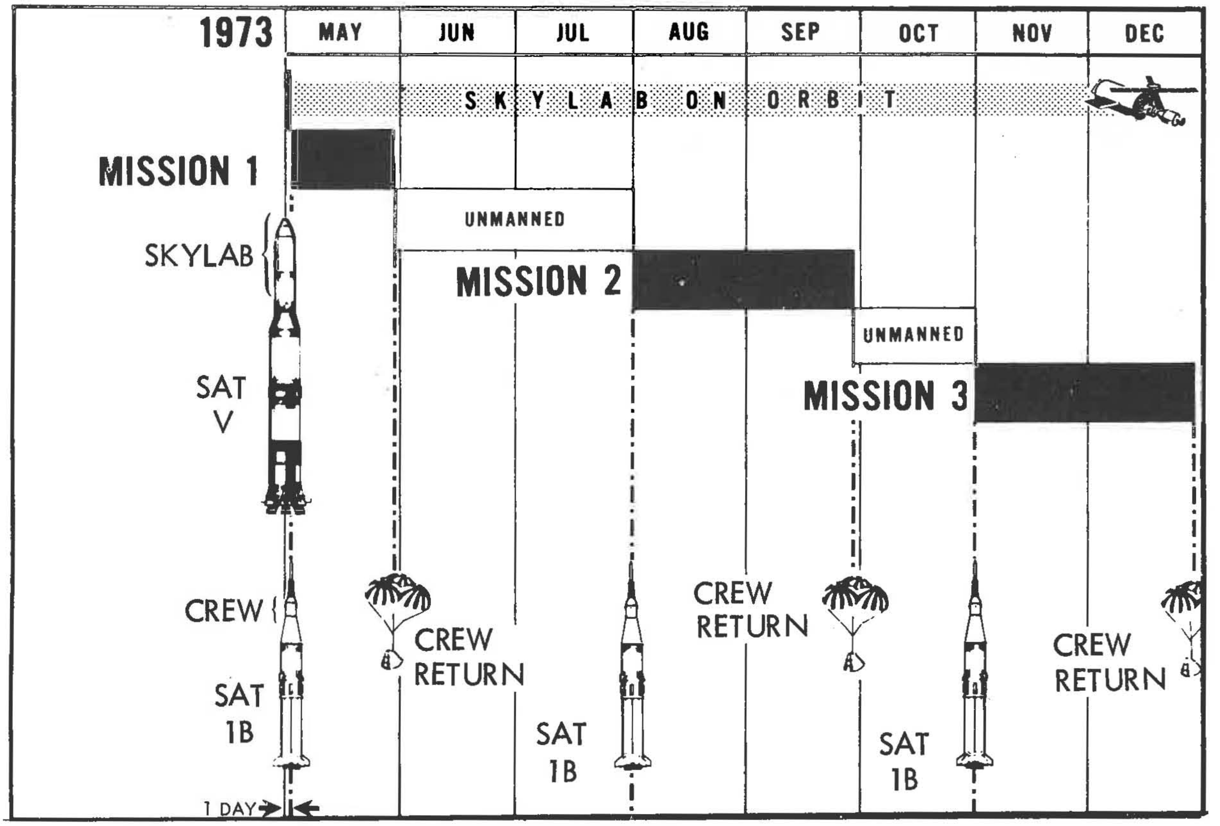


Fig. 2 Skylab Launch Schedule

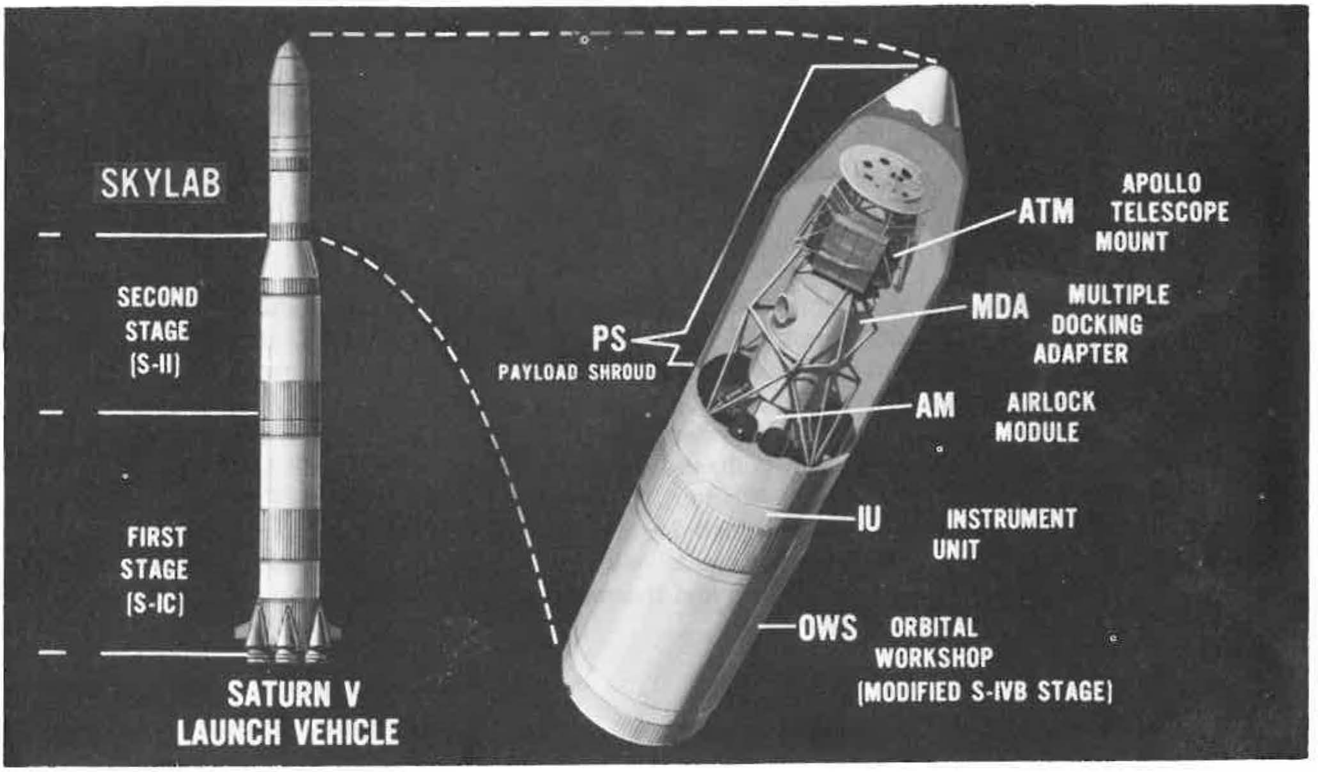


Fig. 3 Skylab Launch Configuration

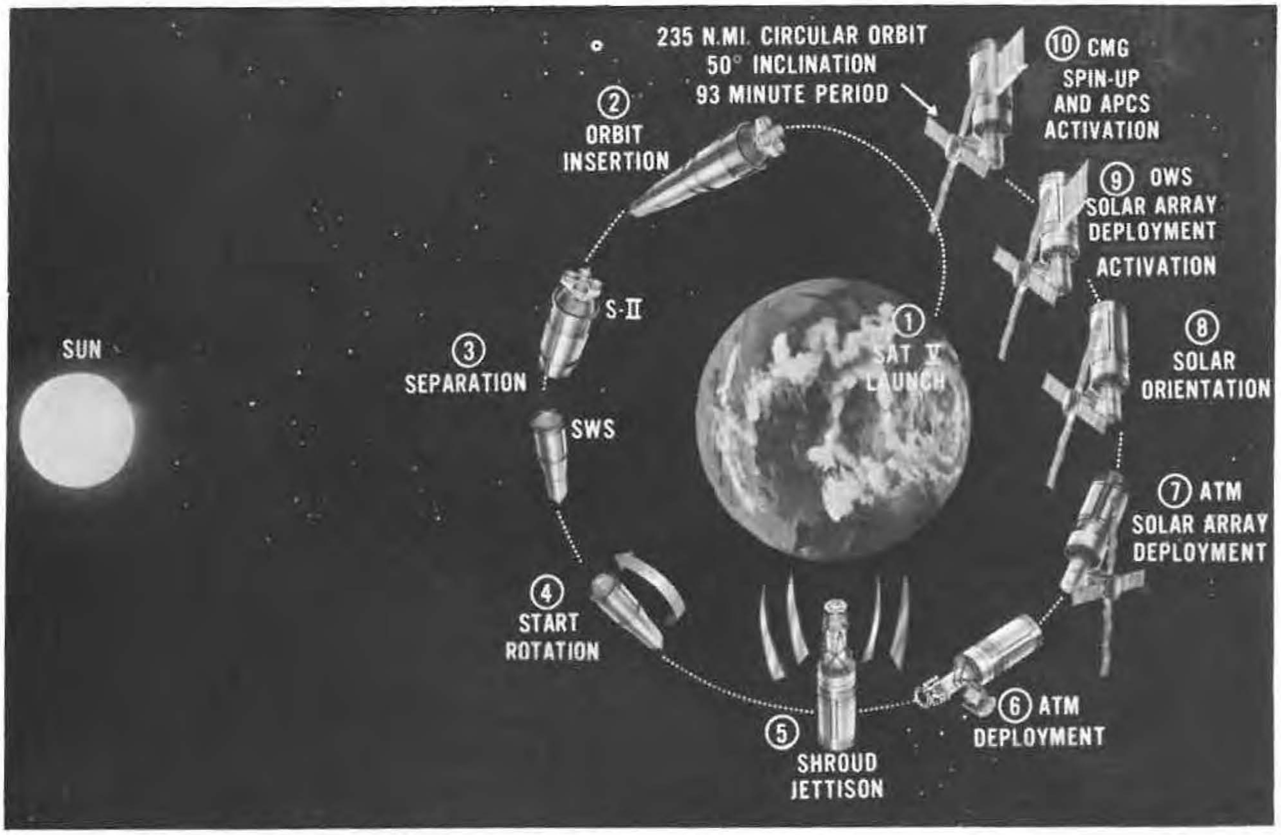


Fig. 4 Skylab Orbit Insertion and Deployment Sequences

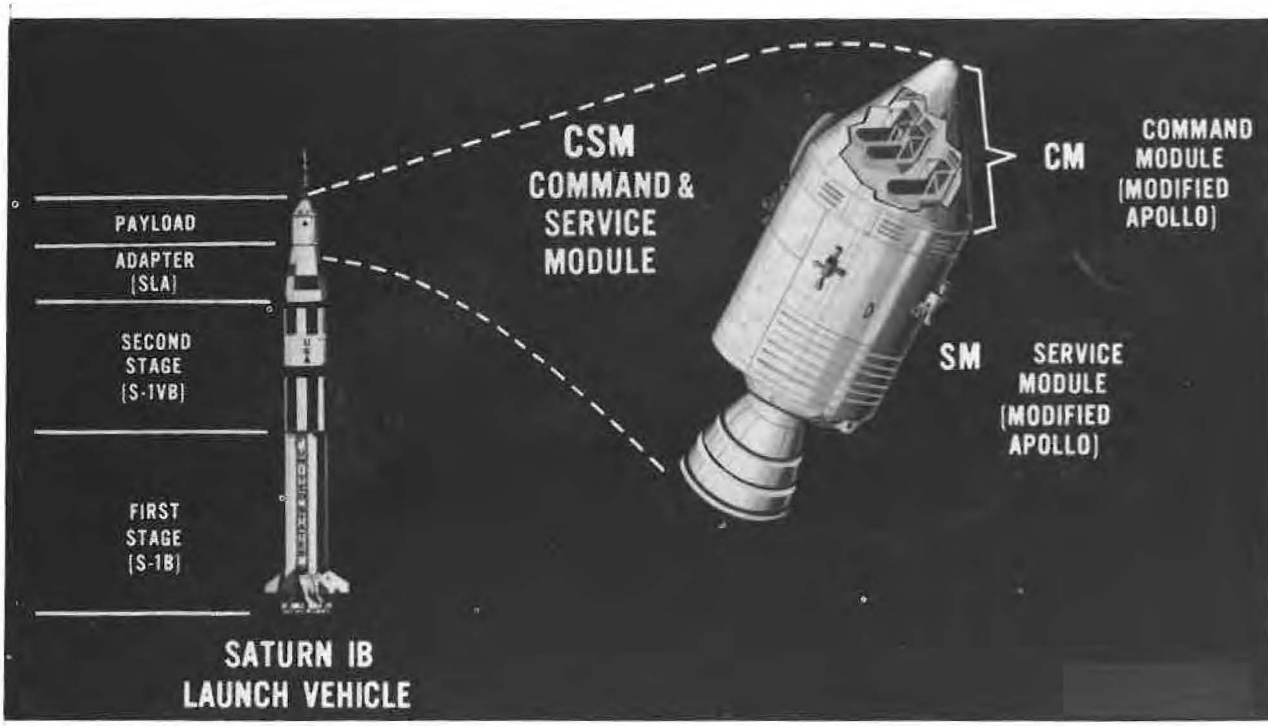


Fig. 5 Command & Service Module Launch Configuration

For the 28 days of the first manned mission, the crew in Skylab will conduct the experiment program and will evaluate the habitability of Skylab. At the end of the mission the crew will prepare Skylab for unmanned operation, and then transfer to the CSM and separate from Skylab. Using the Service Module propulsion system, the deorbit deceleration maneuver will be performed followed by separation of the Command Module from the Service Module, and atmospheric entry and parachute descent of the Command Module to a splashdown in the west Atlantic recovery area (Fig. 7).

The second manned mission will start with another Saturn IB launch approximately 60 days after return of the first crew. Orbit insertion, rendezvous and docking procedures will be similar to the previous flight. The activities performed by the crew after transfer to Skylab will be similar to those in the previous mission. The mission duration will be increased to 56 days with recovery again in the west Atlantic.

Launch of the third manned mission, about 30 days after the second crew returns, will also be from Launch Complex 39. In this mission, also of 56 days duration, the Skylab experiment program will be completed and additional statistical data will be obtained on the crew's adaptability and performance over the planned mission duration. Recovery of this crew and data will occur in the mid-Pacific area.

Vehicles

During the program, the complete orbital vehicle has been given several names: cluster, orbital assembly, and Skylab. In this document the name cluster is used for the complete orbiting vehicle and the name Skylab is used for the laboratory that houses the experiments, crew quarters, and systems necessary for its operation. Thus, the cluster consists of Skylab with a Command and Service Module (CSM) attached to it (Fig. 8 and 9). Skylab, in turn, consists of five modules permanently attached to each other: the Orbital Workshop (OWS), the Airlock Module (AM), the Multiple Docking Adapter (MDA), the Instrument Unit (IU), and the Apollo Telescope Mount (ATM) with its deployment mechanism. The function and configuration of each module is described in the following paragraphs.

Orbital Workshop (OWS)

The OWS is the primary on-orbit living and working quarters for Skylab crews. It is made from the structure of a S-IVB stage (the second stage of the Saturn IB booster) and is equipped to house the crew of three astronauts for uninterrupted periods of up to 56 days (Fig. 10). The workshop, a cylindrical shape, is 22 feet in diameter and about 48 feet long.

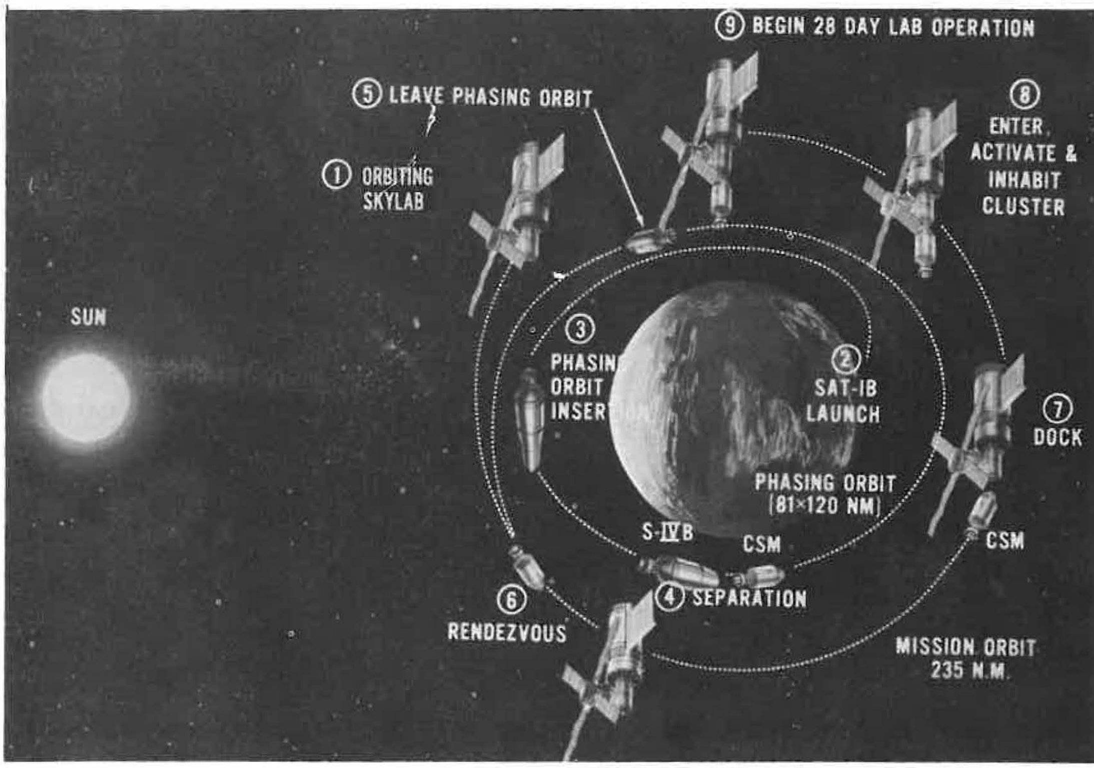


Fig. 6 Crew Launch and Rendezvous with Skylab

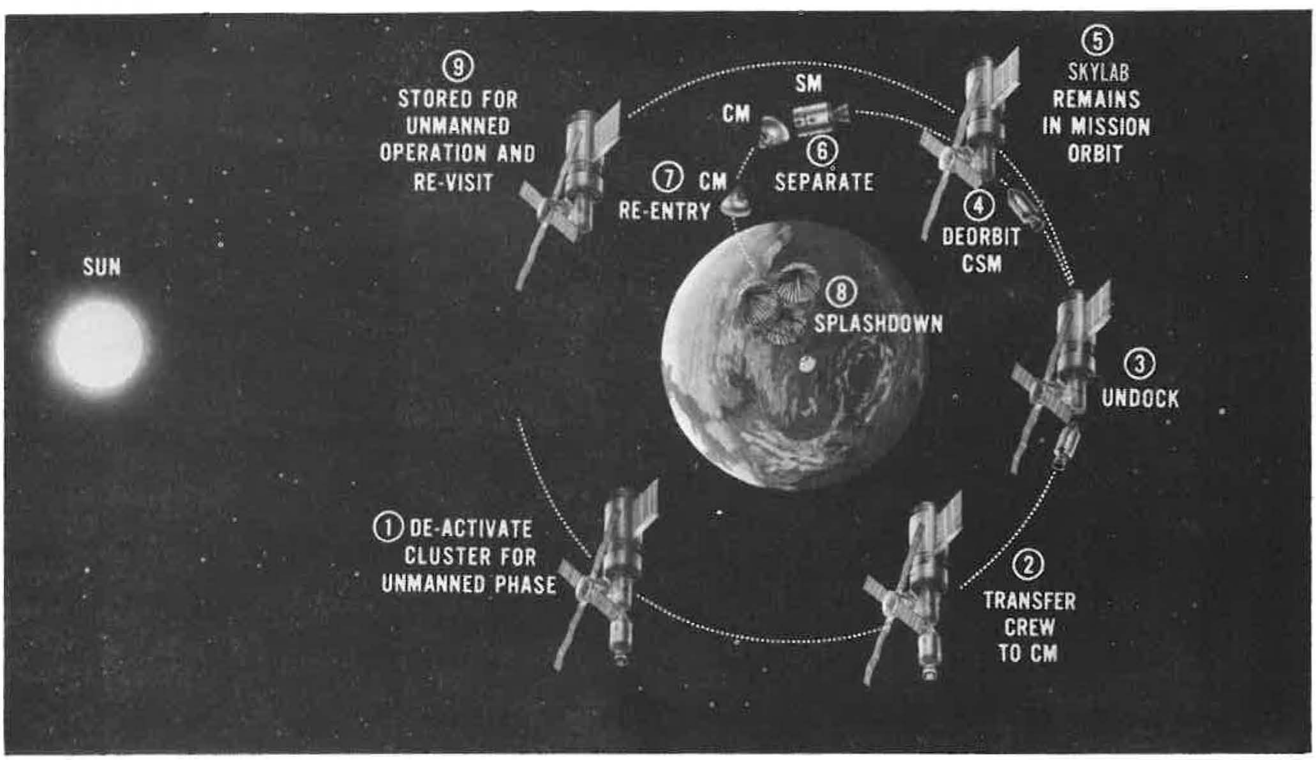


Fig. 7 Crew Return

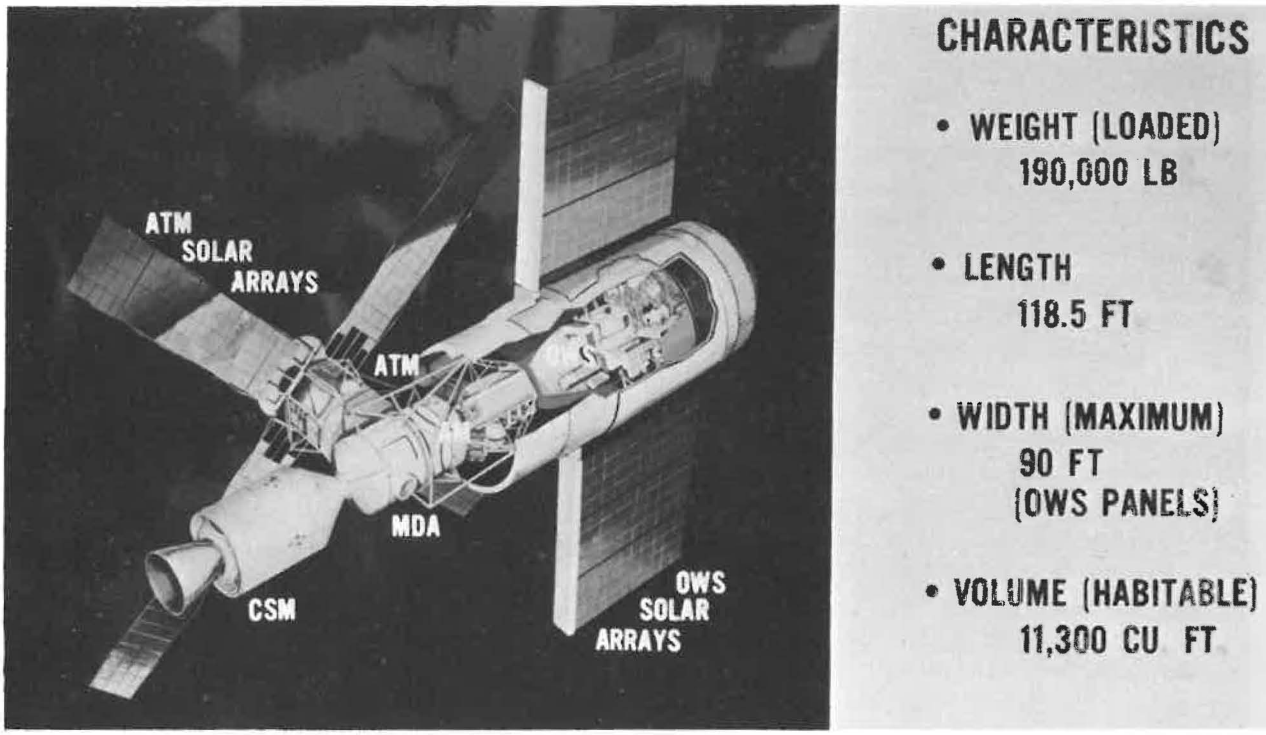


Fig. 8 Skylab Orbital Configuration

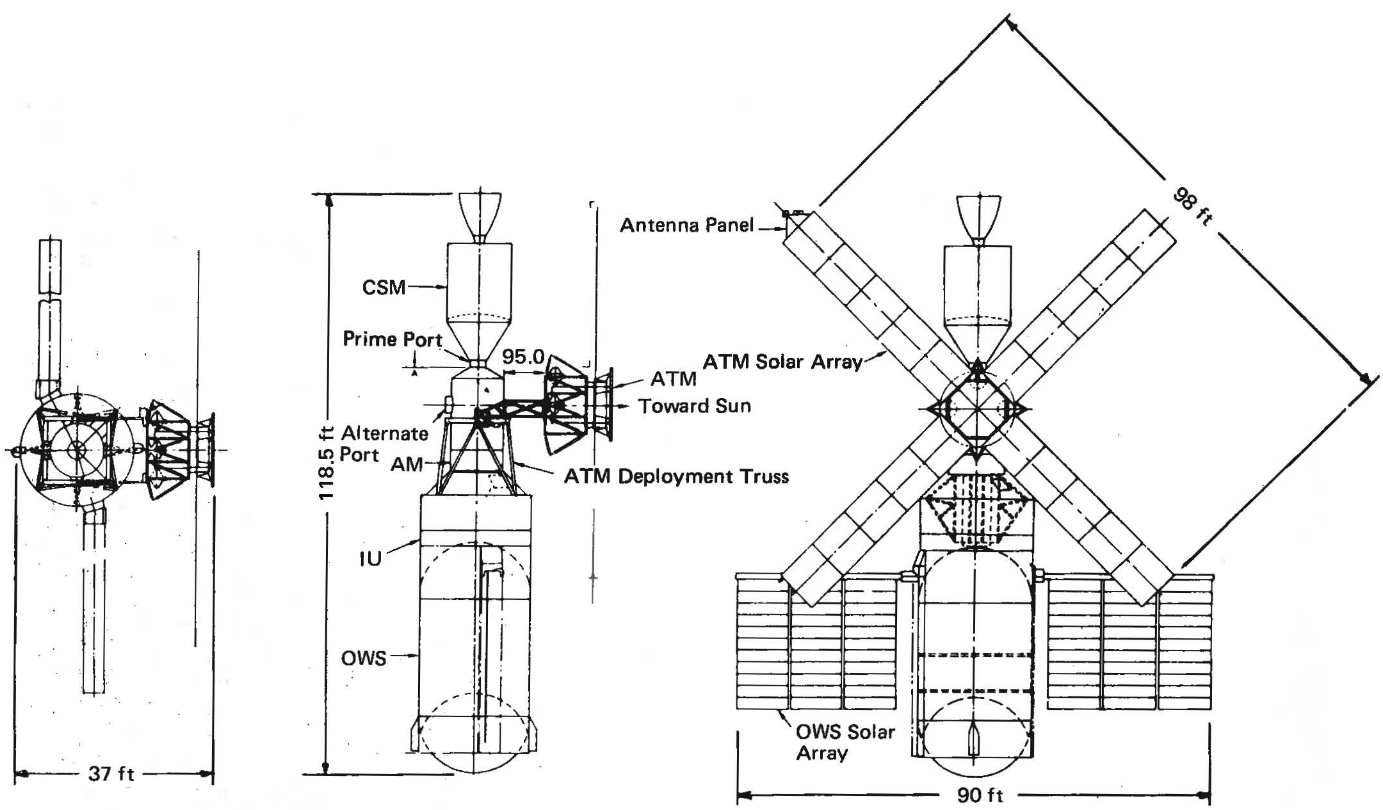


Fig. 9 Skylab General Arrangement

The interior of the OWS is divided into two major compartments. The larger, upper compartment, has been fitted out to form a two-level habitable area. The lower level provides crew accommodations for sleeping, food preparation and consumption, hygiene, waste processing and disposal, and performance of certain experiments. The upper level consists of a large work/activity area and houses water storage tanks, food freezers, storage provisions for film, the scientific airlocks, the mobility and stability experiment equipment, and equipment for other experiments. The compartment below the crew quarters is called the waste tank and is a container for liquid and solid waste and trash accumulated throughout the mission.

Solar arrays, consisting of two wings covered on one side with solar cells, are mounted outside the workshop to generate electrical power to augment the power generated by another set of solar arrays mounted on the Apollo Telescope Mount. Thrusters are provided at one end of the workshop to be used when needed in changing the orientation of the cluster. A shield envelopes the workshop some six inches from the outer surface to provide protection against micrometeoroid damage to inhabited areas of the workshop.

Airlock Module (AM)

The AM is the environmental and electrical control center for Skylab and the module containing the port through which the astronauts egress when performing extravehicular activity (EVA). It is attached to the forward end of the Orbital Workshop and provides structural support to all modules mounted forward of the workshop.

The Airlock Module consists of two concentric cylinders with truss structures bridging the annular gap (Fig. 11). The outer cylinder, the Fixed Airlock Shroud (FAS), has the same diameter as the workshop (22 ft) and is attached to its forward end. The inner cylinder, or tunnel, contains the airlock and constitutes the passageway through which the Skylab crews can move between the Multiple Docking Adapter and the workshop. The forward end of the inner cylinder supports the Multiple Docking Adapter while the forward end of the Fixed Airlock Shroud is the base on which the tubular structure supporting the ATM is mounted.

The airlock, the central portion of the tunnel, has two hatches that close off each end of the central cylinder, and a third hatch located in the outer wall that is the door through which the crew can pass to perform tasks in space. Closing the two hatches before opening the EVA hatch ensures that the atmosphere within the rest of the cluster is retained. The tunnel section also houses the controls for cluster pressurization and atmosphere purification, electrical power and communications, and the cluster malfunction alarm system (the caution and warning system).

High pressure containers, storing the oxygen and nitrogen which provide the Skylab internal atmosphere, are mounted between the Fixed Airlock Shroud and the tunnel.

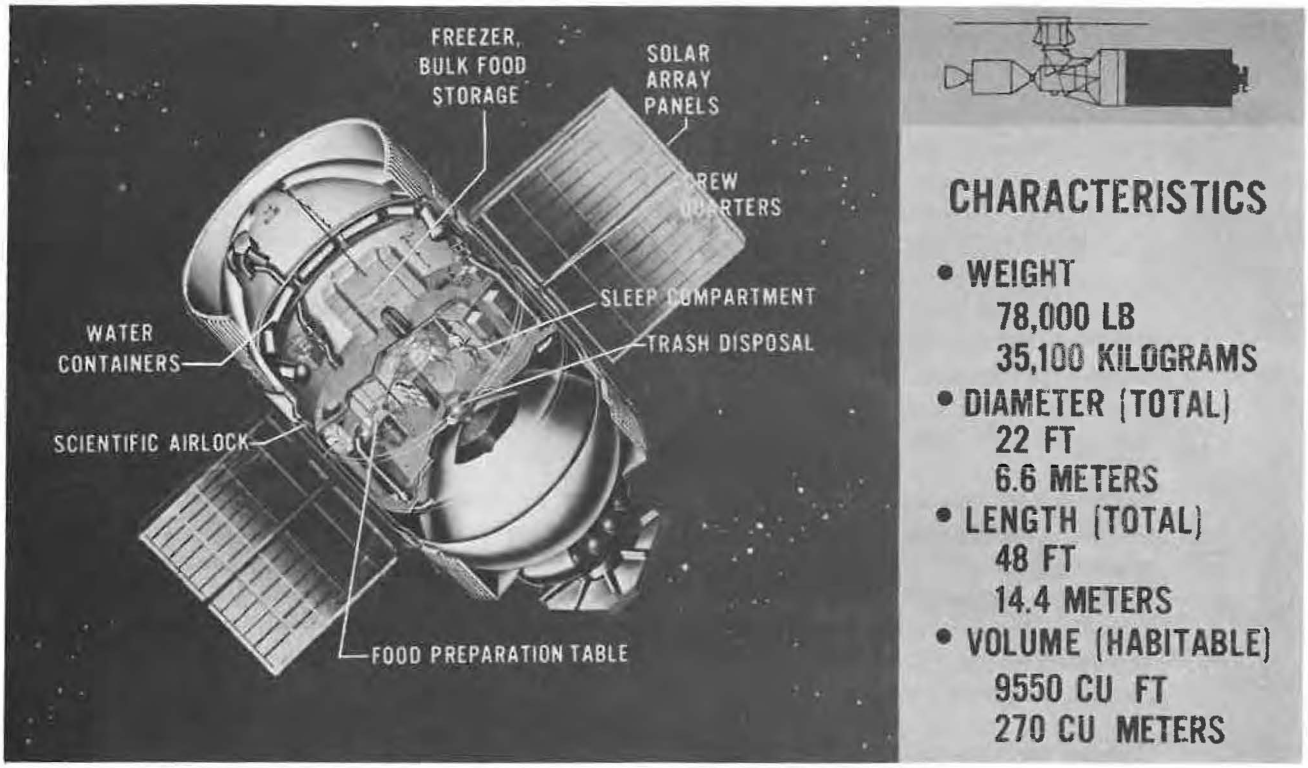


Fig. 10 Orbital Workshop (OWS)

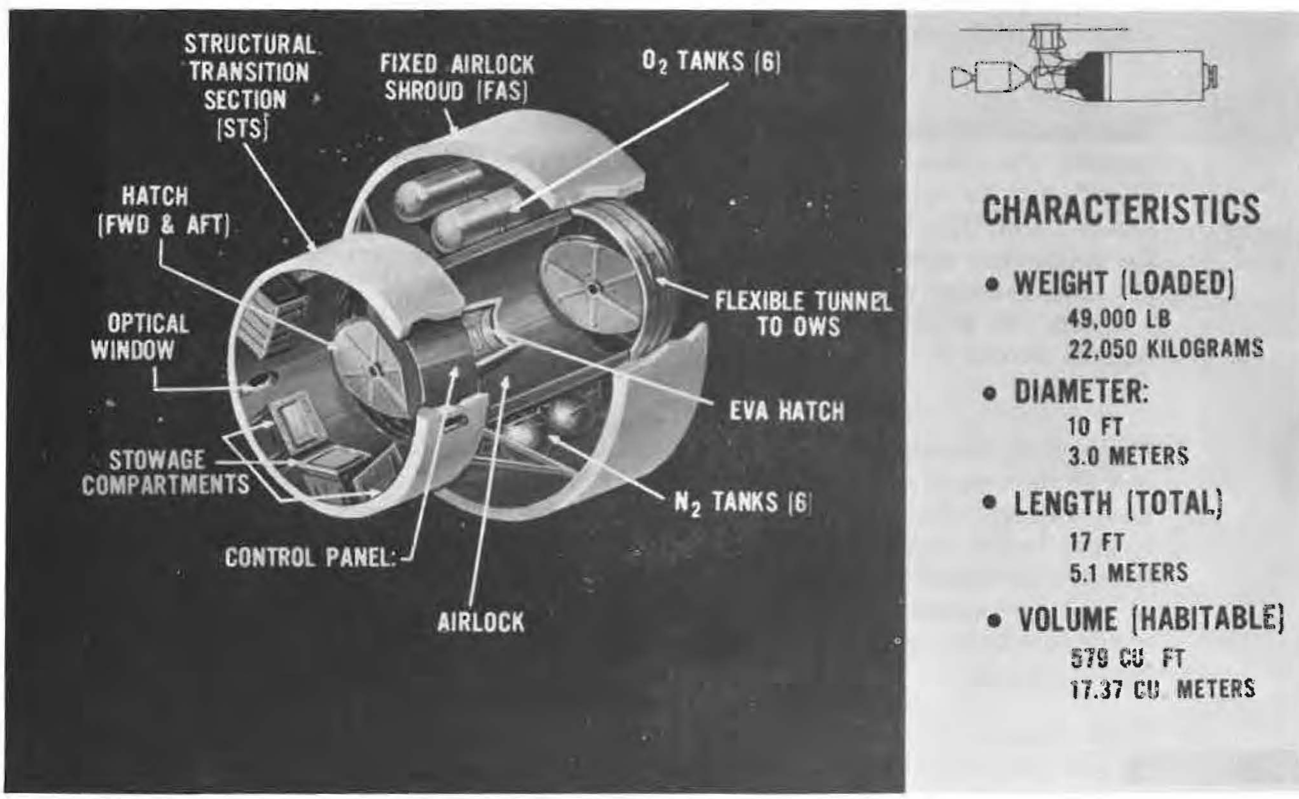


Fig. 11 Airlock Module (AM)

Multiple Docking Adapter (MDA)

The MDA provides the docking port for the arriving and departing manned CSMs and is the control center for ATM and Earth resource experiment package (EREP) experiments. It is mounted on the forward end of the Airlock Module and provides structural support to CSMs docking at its ports. The MDA is a 10½ foot diameter cylinder and is slightly over 17 feet long.

Two ports are provided on the MDA for docking the Command and Service Module. The primary port is axial and is located at the forward end, and the alternate port is radial and is located on the side of the module (Fig. 12). Cameras and EREP sensors are located adjacent to the alternate docking port; some look through a window in the wall, others actually protrude through the wall. Vaults, provided for storage of cameras and film for the Apollo Telescope Mount experiments protect the film from the radiation experienced at orbit altitude.

The control and display console for the Apollo Telescope Mount is located at the rear of the module and contains all the controls and instruments required for operation and observation of the ATM solar astronomy experiments. Two television screens are provided by which the solar activities being studied can be monitored by the observing astronaut. This control and display console also contains the instruments and controls for the ATM attitude control system and for the ATM electrical power system (Fig. 13).

Apollo Telescope Mount (ATM)

The Apollo Telescope Mount houses a sophisticated solar observatory. It also provides attitude control to the cluster, and by means of its solar arrays provides about half the electrical power used by the cluster.

The ATM consists of two concentric elements. The outer element, the rack, is an octagonal structure 11 feet from side to side and 12 feet high. The inner structure is the solar experiment canister and is about 7 feet in diameter and 10 feet long (Fig. 14).

The rack, in addition to supporting the canister, supports the four ATM solar arrays and contains the components of the attitude control system, the ATM communications system, and the thermal control system that maintains the temperature of ATM equipment within the required limits.

The canister is mounted in the rack on gimbals which allow it to rock 2 degrees about two mutually perpendicular axes, and by a roll ring that allows the canister to rotate about its axis. These features make it possible to point the experiments at their targets with greater precision than can be accomplished with the cluster.

Two work stations are provided at which an astronaut can perform the EVA task of changing the cameras and film magazines for the solar telescope.

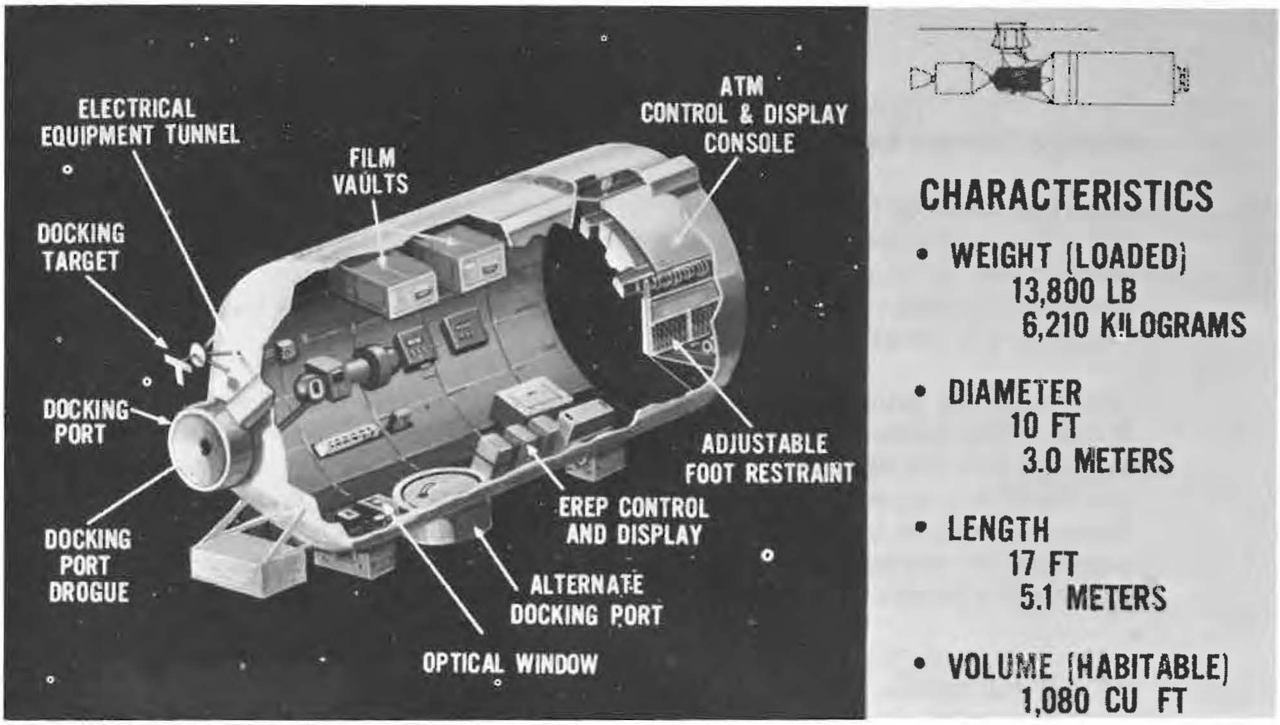


Fig. 12 Multiple Docking Adapter (MDA)

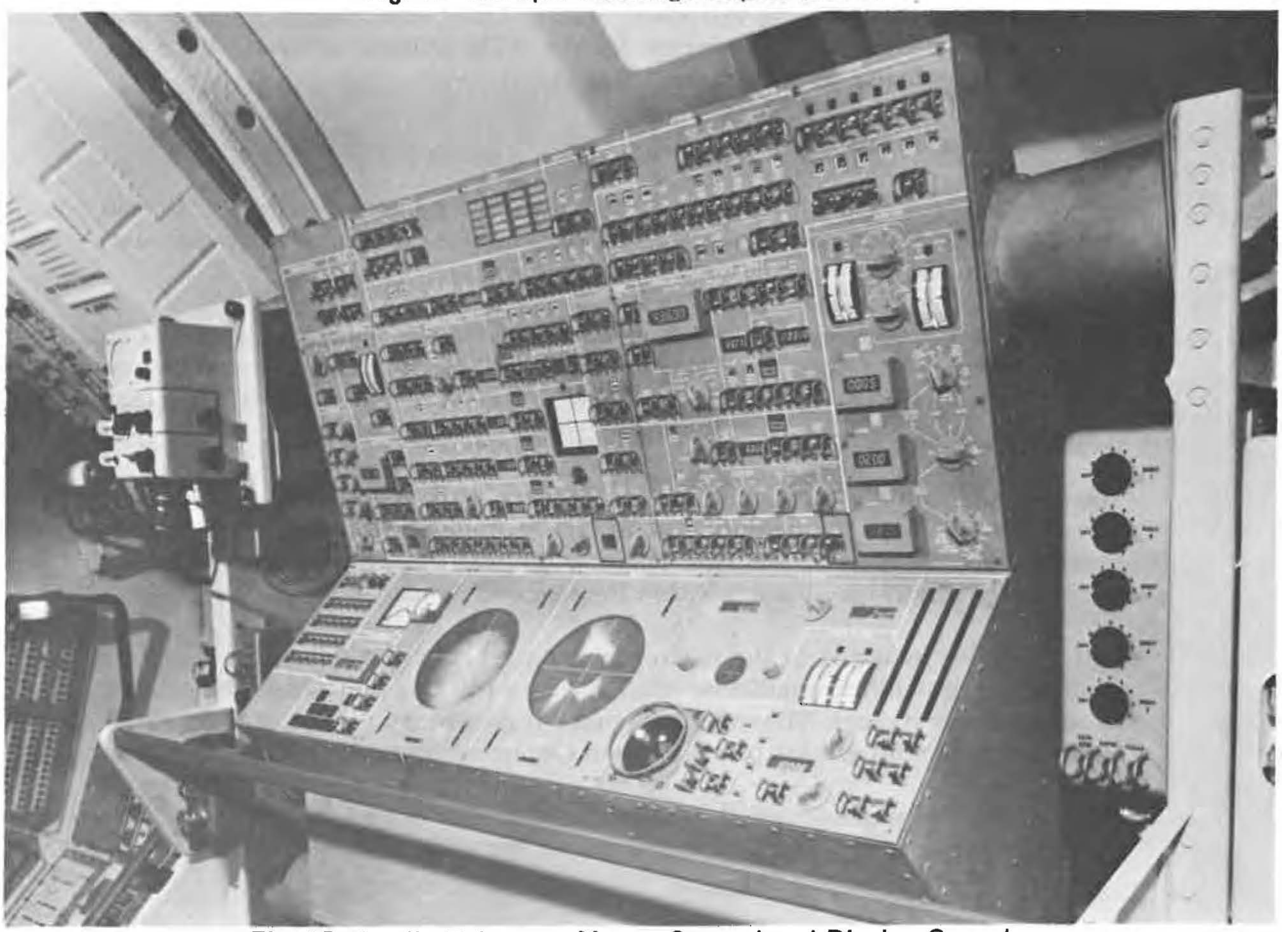


Fig. 13 Apollo Telescope Mount Control and Display Console

The ATM support structure, which connects the rack to the forward end of the Fixed Airlock Shroud on the Airlock Module, incorporates a deployment mechanism that rotates the ATM 90 degrees from its launch position in front of the Multiple Docking Adapter to its operating position alongside the MDA (Fig. 15). During launch and ascent to orbit, the ATM rack is directly supported by the Payload Shroud. When the shroud is jettisoned, the support structure assumes the structural support task.

Instrument Unit (IU)

The Instrument Unit, the launch vehicle control center, is a cylindrical structure 22 feet in diameter and 3 feet high. This unit contains the equipment that will guide the launch vehicle from liftoff through the separation of Skylab from the second stage of the Saturn V booster (Fig. 4). Following separation, the Instrument Unit provides power and sends commands to various Skylab systems which in turn rotate Skylab 180 degrees, turn on refrigeration systems, jettison (discard) the Payload Shroud, roll the cluster so that the Apollo Telescope Mount will be pointed toward the Sun, deploy the OWS meteoroid shield, and pressurize Skylab with oxygen (Fig. 4). All of this activity takes place during the 7½ hours of the Instrument Unit's lifetime. The unit has no function after its own batteries expire.

Payload Shroud (PS)

The Payload Shroud protects the Apollo Telescope Mount, the Multiple Docking Adapter and part of the Airlock Module during launch and boost to orbit. Before launch it provides weather protection to the enclosed modules. During launch and powered ascent it provides protection from the air loads resulting from flight through the atmosphere, and structural support to the ATM (Fig. 3).

The shroud is built in four sections to facilitate jettison after orbit insertion (Fig. 4). Following jettison, the panels deorbit and burn up in Earth's atmosphere.

Command and Service Module (CSM)

The CSM, the crew ascent and descent vehicle, consists of the manned Command Module (CM) and the unmanned Service Module (SM). The Command Module (CM) (Fig. 16) is conical in shape, about 13 feet in diameter and 12 feet high, and contains a crew compartment with a habitable volume of about 210 cubic feet (approximately 7 feet wide, 6 feet high, and 4 feet from front to back). A docking tunnel extends from the crew compartment to the nose of the vehicle to allow the crew to enter the Multiple Docking Adapter after docking. At the outer end of the tunnel is a pressure-tight hatch that can be removed by the crew. Twelve latches are also located at the outer end of the tunnel to automatically attach the Command Module to the MDA docking port.

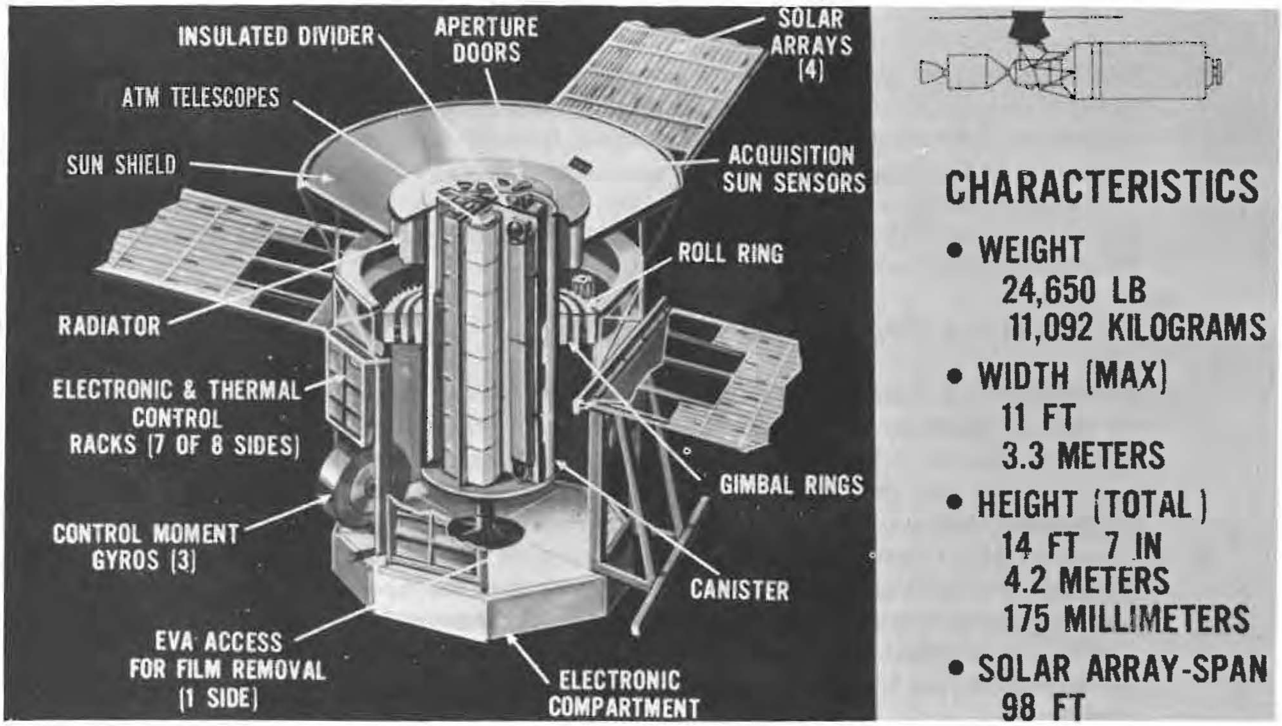


Fig. 14 Apollo Telescope Mount (ATM)

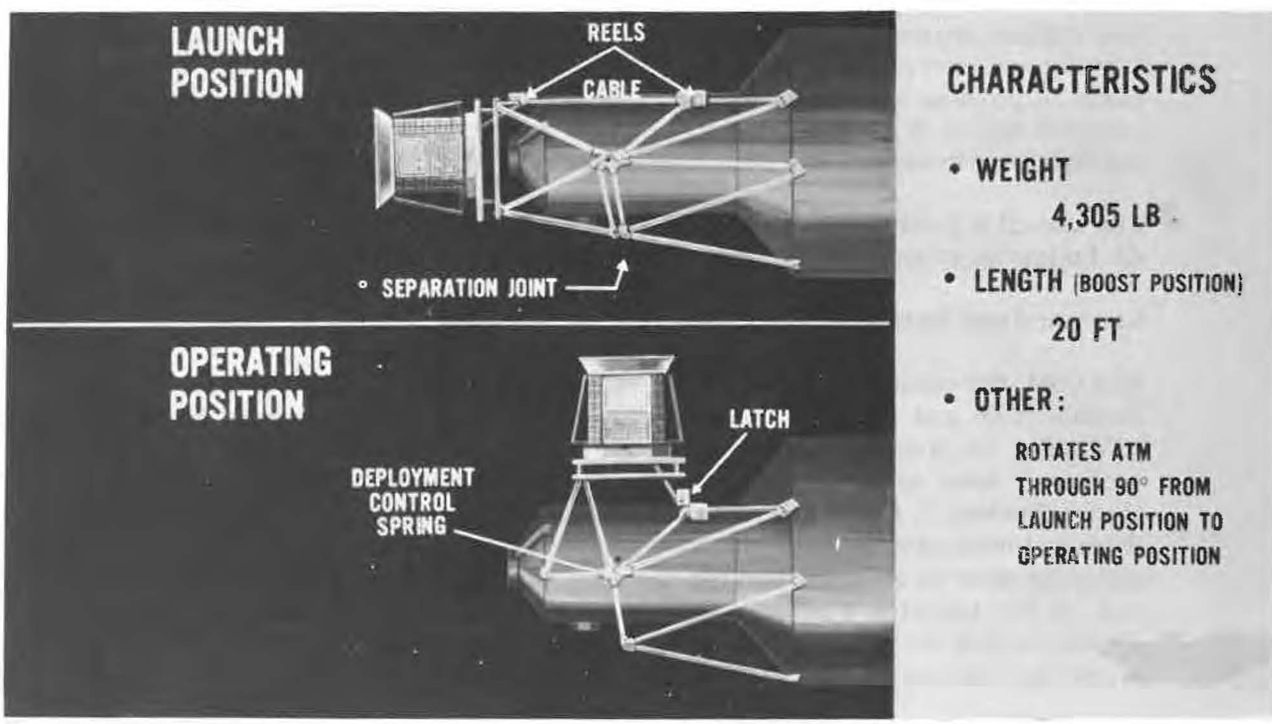


Fig. 15 ATM Deployment Mechanism

Within the Command Module are CSM attitude control and guidance systems, batteries, oxygen containers, control and display panels for the Command and Service Module systems, the couches that support the crew during launch, ascent, reentry and landing, stowage compartments for the consumables needed on the way up and back down, and stowage provisions for equipment to be taken to or returned from Skylab.

The crew compartment is surrounded by a heat shield that is coated with an ablative material designed to burn away during reentry and so dissipate the intense frictional heat.

The Service Module (SM) (Fig. 17) is about 13 feet in diameter and about 25 feet long. This unmanned vehicle contains the services and supplies that do not require direct crew accessibility during flight. These include the main CSM propulsion system with its 20,000 pound thrust engine, a smaller propulsion system (reaction control system) for maneuvering the spacecraft, fuel cells for generation of electrical power during ascent, oxygen for breathing, and radiators for spacecraft cooling. The Service Module remains attached to the Command Module for all but the last half hour of the mission. Separation occurs just before atmospheric reentry and the module burns up in the atmosphere and is therefore not recovered.

Skylab CSMs are basically Apollo CSMs. Because of the different role of the CSM in Skylab, however, the capacities of some systems have been modified. In the Apollo program the CSM was required to be fully operating and self-sustaining for a period up to 14 days. In Skylab, the CSM is fully operating and self-sustaining only during ascent to docking and descent to Earth. For the rest of the 28- or 56-day Skylab missions, the CSM is "powered down" and sustained by Skylab.

Systems

A brief summary of the Skylab systems and their functions is presented in the following paragraphs.

Attitude Control

The function of controlling the attitude of Skylab is the responsibility of the attitude and pointing control system (APCS). This function includes rotating to predetermined attitudes (orientations), holding the required attitudes for as long as necessary, and providing precise pointing for the Apollo Telescope Mount experiments. In an attitude change, the system performs as follows:

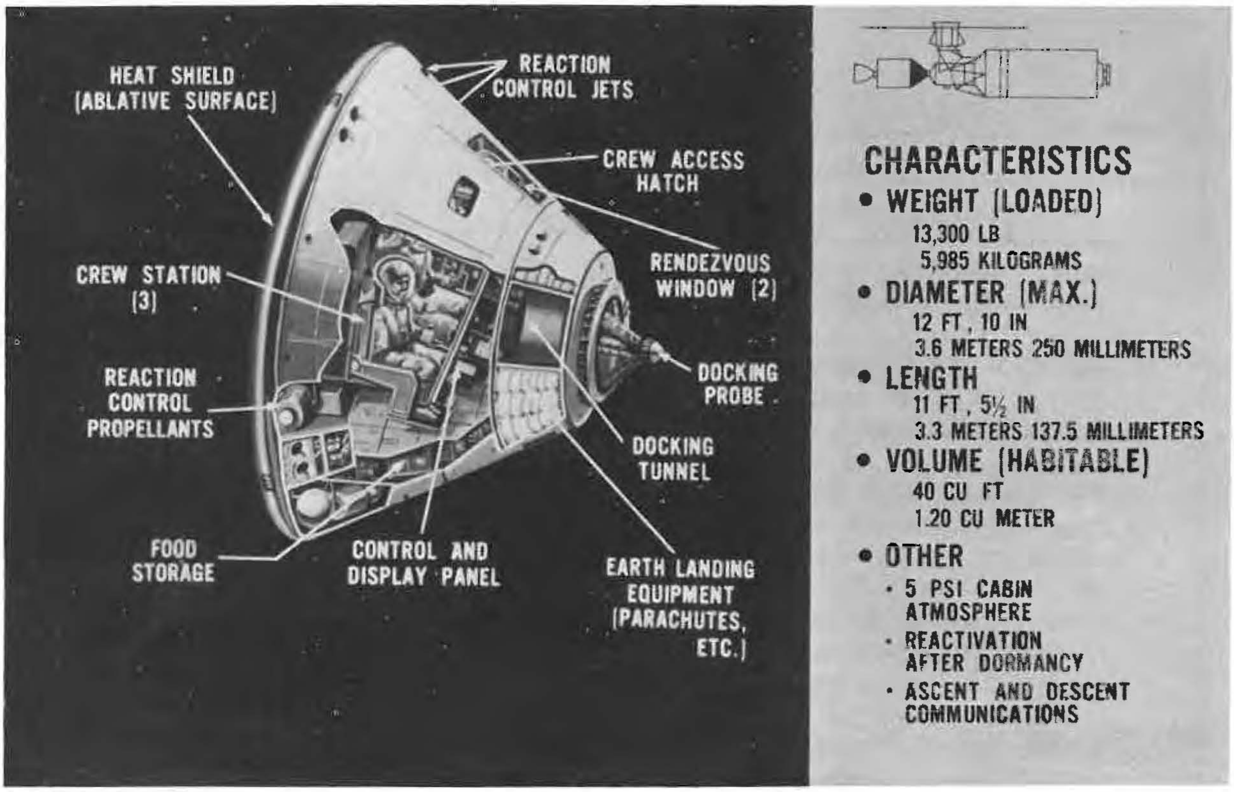


Fig. 16 Command Module (CM)

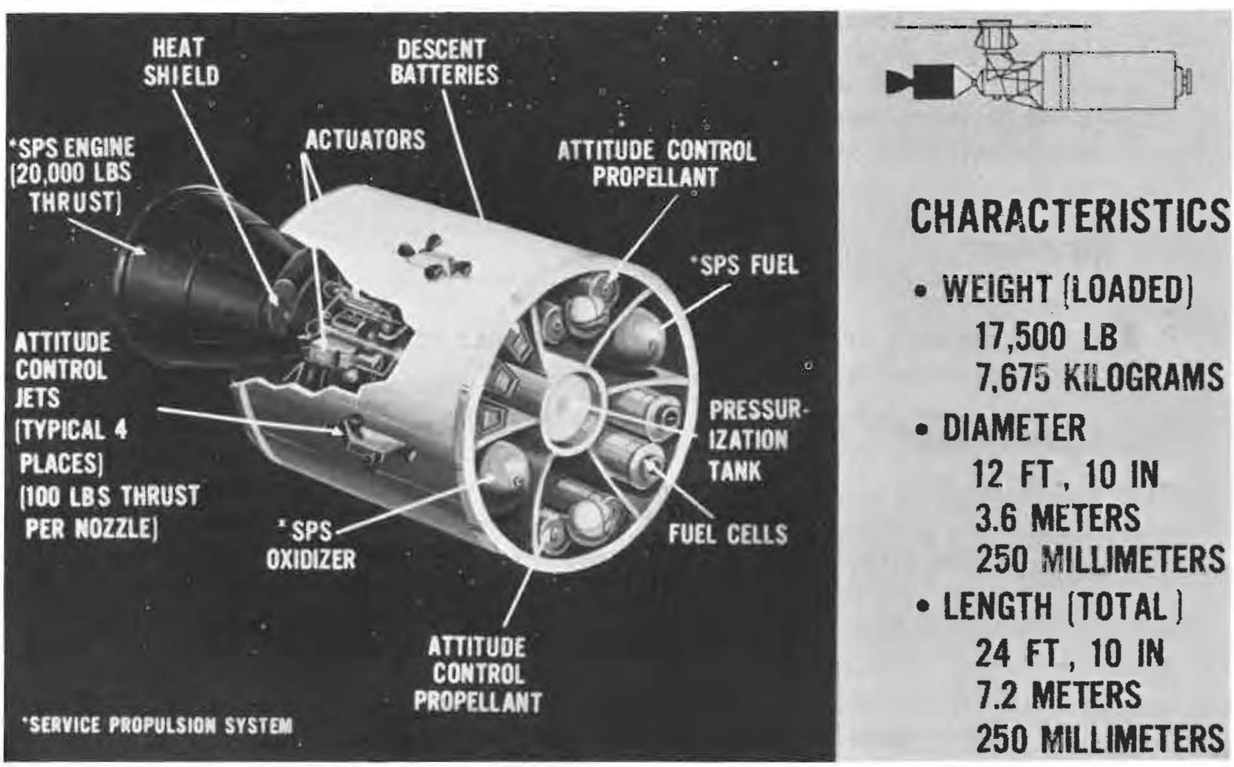


Fig. 17 Service Module (SM)

- Checks present attitude;

- Activates attitude change mechanism and initiates change maneuver;

- Measures attitude and rate of change of attitude during maneuver;

- Terminates maneuver when attitude attained matches attitude required.

The prime attitude sensing equipment in Skylab is a rate gyro system that measures vehicle attitude rates and derives vehicle attitude. Reference attitude information is provided by a Sun sensor that indicates whether it is pointed at the Sun or not, and a star tracker that senses the location of predetermined stars (Canopus and Achernar in the southern hemisphere, for example) and indicates their direction relative to the Skylab axes.

The prime mechanism for executing maneuvers is the control moment gyros (CMG) which are momentum storage devices. Three gyro wheels (rotors) are mounted in gimbals with their axes nominally mutually perpendicular. Each rotor is 22 inches in diameter and spins at about 9000 rpm. To maneuver the spacecraft, the astronaut inputs the desired attitude to the ATM digital computer. The computer compares the desired attitude with the present spacecraft attitude (derived from rate gyro data). If rotation is required, the axis of one (or more) of the CMGs is shifted (torqued) by computer command which causes a reactive force and rotation of the spacecraft in the desired direction. When the desired attitude is achieved, torquing of the CMG is terminated.

A secondary maneuvering system, the thruster attitude control system (TACS), consists of a series of gas expulsion nozzles mounted on the aft end of the Orbital Workshop which by thrusting in the required direction rotate the vehicle to the new attitude. Either the TACS or the CMGs can provide the basic pointing accuracy required by Skylab. The normal mode, however, is to use the CMGs for primary control and maneuvers and to use the TACS for backup.

To satisfy the very accurate pointing requirements of the Apollo Telescope Mount solar observation experiments (±2½ seconds of arc or less than an inch a mile away), a vernier pointing system rotates the experiment canister relative to the ATM.

Electrical Power

During orbital operation of Skylab, all the electrical power used is generated by two sets of solar arrays. One array deploys in the form of two "wings," one on each side of the Orbital Workshop; the other array consists of four "wings" deployed from the Apollo Telescope Mount. Under ideal conditions of continuous sunlight and minimal adverse effects, such as illumination of the back of the arrays by reflected light from Earth, the OWS arrays can generate over 12,000 watts of electrical power, and the ATM arrays can generate about 11,000 watts.

The Skylab orbit, however, takes the vehicle out of sunlight for more than one-third of the 1½ hour orbit duration in all but a few of the over 4000 orbits in the eight-month mission. In order that the Skylab systems can operate during the periods of orbital darkness, batteries must be provided, and their charging becomes a continuous load on the solar array output during sunlight periods. Taking into account the interchange of day and night periods in each orbit and the battery charging requirements, the power available is about 3700 watts from the OWS array and about 3500 watts from the ATM array.

The OWS and ATM electrical systems are each self-contained. Each has its own arrays, batteries, battery chargers and regulators, and essentially provides power for its own part of the Skylab vehicle. However, a power sharing capability is provided so that peak power demands in one system can be satisfied by the other.

Power from the OWS arrays is routed to the Airlock Module. The AM houses the OWS system's batteries, chargers, etc., and is the center from which conditioned power is distributed to the Multiple Docking Adapter and to the workshop. The ATM electrical power system components are housed in the ATM rack (Fig. 14).

Most electrical-power-using equipment is permanently wired to power distribution buses in the various modules. There are, in addition, several utility outlets in the MDA, the Airlock Module, and the OWS into which portable experiment equipment, tools, lights, and a vacuum cleaner can be plugged. These outlets provide 28-volt DC power.

A third power source, available only to the Command and Service Module during ascent to orbit, is the CSM electrical power system that generates power from oxygen/hydrogen fuel cells. After docking to the MDA, the fuel cells are shut down, the hydrogen supply is dumped overboard, the oxygen supply is used to augment the Skylab environmental control system, and the powered-down CSM draws power from the Skylab electrical power system. After undocking for return to Earth, the CSM relies on its batteries.

Environmental and Thermal Control

The prime functions of this system are to provide a breathable atmosphere inside Skylab and to maintain the temperature of crew and equipment within tolerable limits. Before each crew arrives, Skylab is pressurized to 5 psi, with a mixture of oxygen and nitrogen (approximately 76% O_2 23% N_2) which assures that the astronauts breathe the same amount of oxygen as they would on Earth. The atmospheric gases are stored in gaseous form in bottles mounted on the Airlock Module (Fig. 11). Flow regulator valves ensure that the correct pressure and proportional mix of gases is maintained.

Atmospheric purification and humidity control are achieved by passing the gases through carbon dioxide removal equipment and through water removal condensers. Odors are removed by passing the gases through charcoal filters, in this case activated coconut shell charcoal.

Carbon dioxide (CO_2) removal on Skylab is an advancement over the Apollo CO_2 removal process. The Apollo equipment consisted of canisters that absorbed CO_2 until saturated. The number of canisters depended on the length of the mission. Since the manned duration of Skylab is ten times the mission duration for which Apollo systems were designed, a reusable system is used. The Skylab CO_2 removal equipment consists of two units each containing two beds for absorption of carbon dioxide. The beds operate on a reversible cycle. After absorbing CO_2 for 15 minutes, the bed undergoes a process that expels most of the CO_2 overboard during which time the other bed has been switched to the absorbing mode.

Skylab is subjected to two significant thermal environments: the intense heat of the Sun and the intense cold of dark space. Passive thermal control, in the form of insulation and thermal coatings on the workshop, Airlock Module, and Multiple Docking Adapter, is used to attenuate the effect of these influences on internal temperatures.

During normal operating periods, sufficient internal heat is generated by the lighting system, operating equipment and crew to provide comfortable compartment temperatures. During other than normal operating periods, such as the unmanned periods, wider temperature excursions are expected. To control temperature and humidity during these periods, an active thermal control system for the OWS, AM and MDA is provided. This system is centered in the Airlock Module and provides heat through a combination of air duct heaters and radiant wall heaters. The heaters prevent condensation from forming and damaging instruments and equipment. Cooling when required is achieved by passing the atmosphere through heat exchangers that condense the moisture and extract the heat, and radiate it to space through radiators mounted on the MDA.

Heat producing equipment is cooled, if required, by means of thermal conduction to refrigerator-like cold plates. The temperature of these plates is maintained by a liquid coolant that is pumped to heat exchangers where the excess heat is dumped to space through the radiators on the MDA.

Thermal control of the Apollo Telescope Mount is provided by a system of passive control measures, radiant heaters, cold plates, and radiators similar to those used in the crew compartment system. A Sun shield that shelters much of the ATM equipment from direct sunlight is unique to the ATM passive thermal control (Fig. 14).

Instrumentation and Communication

Several functions are provided by the Skylab instrumentation and communication system.

- A 13-station internal communication system enables crew members to talk to each other anywhere in Skylab or outside at the EVA work stations.

- Measurement systems with sensors acquire and process information on the active Skylab systems and experiments. The types of information gathered include atmospheric pressure, temperatures, electrical power system measurements, experiment data, and crew biomedical information from sensors worn by the crew members. The instrumentation system processes all the measurement signals into a form suitable for transmission and transmits or records them depending on the availability of ground communications contacts.

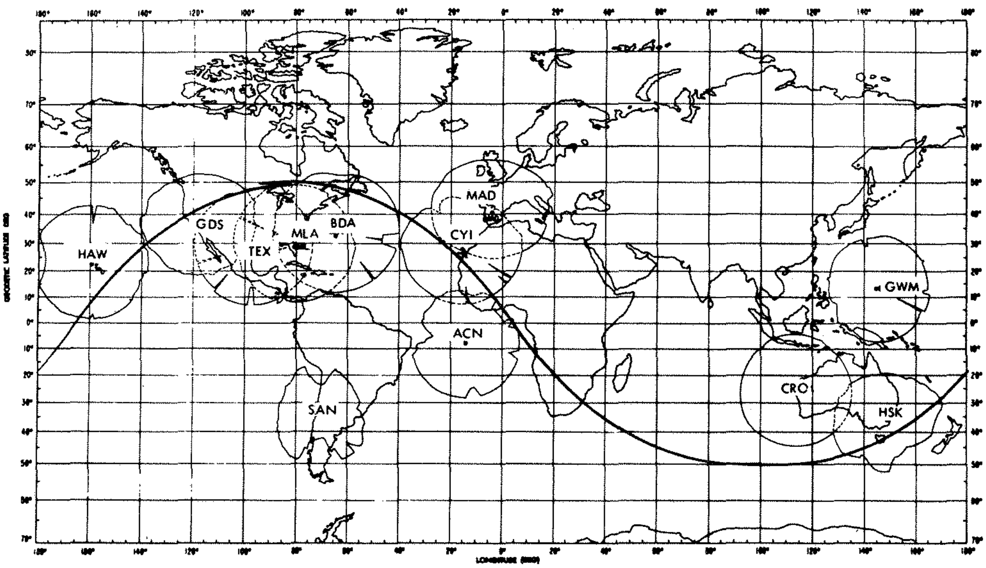
- Spacecraft-to-ground communication is effected through the CSM transmitting and receiving equipment for voice comments between the Skylab crews and the Mission Control Center in Houston, Texas. In addition to voice communication, transmitter/receiver/antenna systems in the CSM, AM, and ATM transmit instrumentation data to Earth and receive and implement digital commands sent from the Mission Control Center.

- A TV system routes television signals from any of the five TV cameras on the Apollo Telescope Mount solar telescopes to the ATM control and display panel. In addition, a portable color television camera is provided for viewing internal activity or astronaut EVA. The TV images are transmitted to the ground through one of the Command and Service Module transmitters.

The spaceborne communication systems are supported by a number of ground stations with transmitting/receiving capabilities. At the radio frequencies used in the Skylab program, contact between Skylab and the ground stations is limited to line-of-sight. The curvature of the Earth thus invokes a limit to the communication range for each ground station. The ideal range is further limited by the local ground features such as mountains, buildings, and even the structure supporting the antenna. Figure 18 shows the communications network for Skylab and indicates the influence of local terrain features on the communication range of each station. All of the stations shown are ground based. One additional station is shipborne and can be moved to an area where communication support is critical.

Habitability

Skylab is a *manned* space program and accordingly contains provisions for feeding, clothing, living, working, personal hygiene, and waste disposal. The long duration of the mission and of the manned occupancy periods, compared with previous United States manned space missions, demands more extensive and varied provisions for feeding than on Mercury, Gemini, and Apollo. Almost 1500 pounds of food will be carried in the OWS. The variety of foods in the crew's menus is evident in the list of the currently planned supplies.



LEGEND:

HAW - HAWAII TRACKING STATION
GDS - GOLDSTONE TRACKING STATION, CALIFORNIA
TEX - CORPUS CHRISTI, TEXAS TRACKING STATION
MIL - MERRITT ISLAND TRACKING STATION, FLORIDA
SAN - SANTIAGO, CHILE
BDA - BERMUDA TRACKING STATION
CYI - GRAND CANARY ISLAND TRACKING STATION
ACN - ASCENSION ISLAND TRACKING STATION
MAD - MADRID TRACKING STATION, SPAIN
CRO - CANARVON TRACKING STATION, AUSTRALIA
GWM - GUAM TRACKING STATION
HSK - HONEYSUCKLE CREEK TRACKING STATION, AUSTRALIA

Fig. 18 VHF Communication Coverage

DEHYDRATED FOODS

Scrambled eggs
Butterscotch pudding
Chocolate pudding
Chicken and rice
Shrimp cocktail
Applesauce
Sausage patties
Cream of tomato soup
Cranberry-orange relish
Grapefruit drink
Orange juice
Pineapple-grapefruit drink
Orange-grapefruit drink
Cocoa
Grapefruit juice
Orange drink
Grape punch
Pineapple drink
Grape drink
Pea soup

READY-TO-EAT FOODS

Peaches
Brownies
Caramel candy
Apricots
Bacon bars
Sugar cookies
Cinnamon toasted bread cubes
Chocolate bars

FROZEN FOODS

- Sirloin strip steaks
- Twice-baked potatoes
- Green beans in mushroom sauce
- Dinner rolls
- Butter
- Ice cream
- Crepes Dianne
- Cheese omelettes
- Bacon strips
- Roast beef au jus
- Au gratin potatoes
- Creamed green peas
- Apple cobbler

"CANNED" FOODS

- Meat balls and sauce
- Frankfurters
- Catsup
- Mustard
- Turkey and gravy

The clothing worn by the astronauts during normal inside activities consists of cotton overalls worn over undershirts and underpants. Two types of pressure suit are provided. One, for extravehicular activity, includes a liquid-cooled undergarment with thermal and micrometeoroid protection on the outside. The other, used only inside Skylab during certain experiments or in emergencies, does not include these features. Laundry facilities are not provided. Soiled clothing is discarded and clean clothing used from the following supply.

Garment	Quantity
Jackets	60
Trousers, pairs	60
Shirts	60
Underwear, sets	210
Boots, pairs	15
Gloves, pairs	15
Constant-wear garments	30

Zero gravity necessitates special provisions for living and working. Moving about becomes much easier since a floating motion resembling a slow motion leap is employed instead of walking; however, handrails and a fireman's pole are provided to help control the motion to avoid painful contact with structure and equipment. Remaining motionless becomes more difficult. Means of holding the astronaut *down* must be provided. In zero gravity the concept of *up* and *down* has little significance as it is as easy for an astronaut to stand on the ceiling as on the floor. However, it is believed that the maintenance of a floor-ceiling appearance in the living quarters may be desirable for psychological reasons.

Fig. 19 Skylab Provisions for Eating

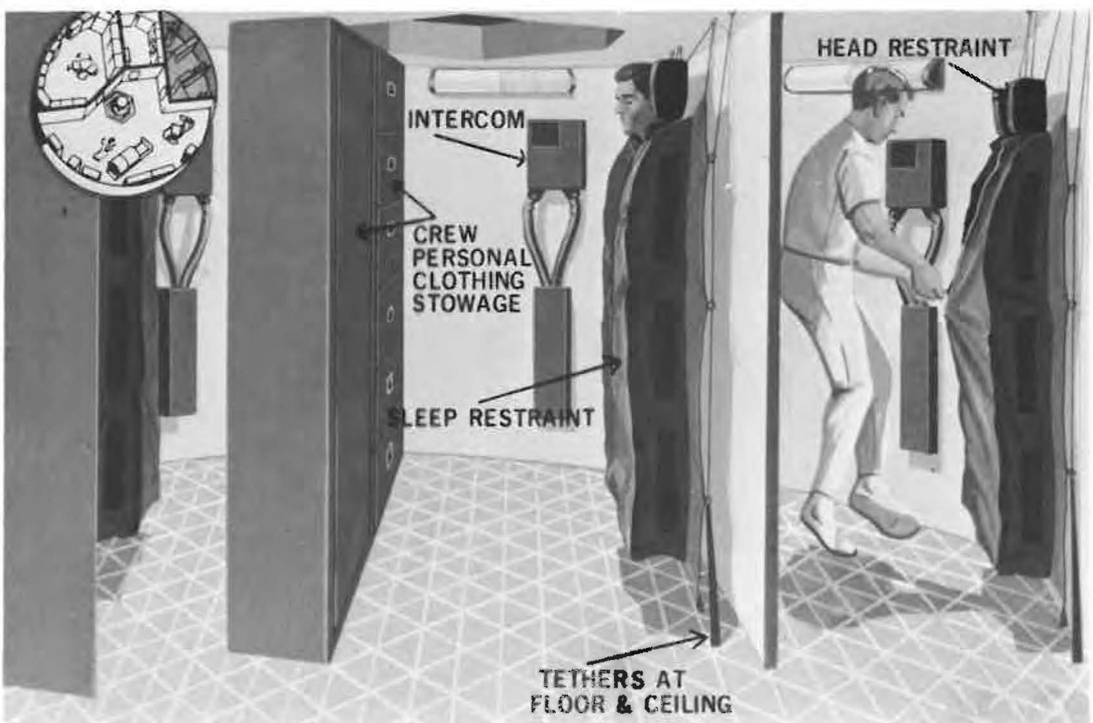


Fig. 20 Skylab Crew Sleep Restraint

A specific orientation for sleeping is not required. Consequently, the sleep provisions consist of a lightweight sleeping bag-like restraint attached to the wall of each private sleeping compartment. The prime purpose of this restraint is to prevent the sleeping astronaut from drifting around his room (Fig. 19 and 20).

Personal hygiene is accomplished using a covered washbowl (from which water cannot escape), wash cloths, and towels. Normal waste disposal, in conjunction with biomedical experiment requirements, involves the collection of samples of bodily waste for analysis, and disposal of the remainder. Freezers are provided for storage of urine samples; fecal samples are dried before storage. All other waste including trash, is transferred to the waste tank below the floor of the crew compartment. An airlock is provided in the floor through which bagged trash can be passed for storage (Fig. 10). All material subject to bacterial decomposition is treated with a bactericide to prevent decay and to prevent bacterial contamination of the rest of Skylab.

IV. Experiments

Physical Science

Earth is a spacecraft in orbit about a Sun. It is surrounded by a near-Earth environment, the atmosphere, which is crucial to the maintenance of life on Earth. Earth and its atmosphere are in turn surrounded by a near-vacuum called space which is environmentally hostile to life. Increased understanding of the balance between the hostility of space and the protection of the atmosphere, or the macroecology of *spaceship Earth* in its solar system, is the purpose of the physical science experiments on Skylab.

Primary to Earth's macroecology is the Sun, its emissions and their influence on Earth's environment. Skylab, and in particular the Apollo Telescope Mount, will carry more than 2000 pounds of solar observation equipment. The instruments used are the largest and most complex ever employed in solar research from an orbiting spacecraft. Most of the observations performed will be of a type not possible from the surface of Earth because of the absorbing and light scattering effect of the atmosphere surrounding Earth.

Four basic features of the Sun's emission are to be studied. The first is called the hydrogen-alpha (H-alpha) emission, a red light emitted by the hydrogen gas near the surface of the Sun. This emission increases greatly during sunspot activity. Photographs of this emission will record this activity and enable correlation with other radiations and observable activity on the solar surface.

The next emission is ultraviolet radiation emanating from the chromosphere which extends 1000 to 2000 miles above the Sun's surface and which has a temperature variation from 5000°C up to more than 100,000°C. Study of this emission will help correlate the presence of different types of atoms in the chromosphere with different types of solar activity.

The third emission is the X-ray radiation coming from the Sun's corona. The solar corona begins about 2000 miles above the solar surface and continues far out into space. Its density is quite low but its temperatures vary from almost 1,000,000°C in quiet places to over 10,000,000°C in certain regions during solar flares. These high temperatures cause the ions and electrons in the corona to emit X-rays that can be photographed by the ATM cameras.

Because of its very high temperatures, the solar corona contains many free electrons that scatter the white visible light radiated from the surface of the Sun. By masking a camera from the intense white surface of the Sun, the faint corona can be photographed out to four million miles from the surface. As the intensity of the corona is a measure of the electron density, much can be learned from photography of this, the fourth emission.

In addition to an extensive solar study, Skylab will carry physical science experiments to investigate (1) the contribution of deep space (beyond our solar system) to Earth's space environment, (2) the characteristics of the Earth's upper atmosphere, and (3) the content of the medium directly surrounding Skylab.

The physical science experiments are individually described on the following pages.

The Apollo Telescope Mount is a solar observatory containing eight telescopes that serve seven solar experiments. All eight telescopes are rigidly mounted and co-aligned with the ATM canister axis. The experiments using these telescopes are described in the following paragraphs.

H-Alpha Telescopes

One of the two H-alpha telescopes provides simultaneous photographic and television pictures; the other operates only in the TV mode. Both telescopes have a zoom capability; however, H-alpha-1 has higher resolution than H-alpha-2. The crew monitors the TV outputs of the H-alpha telescopes to determine areas of interest on the solar disc; for example, sunspots and other solar activity. Aiming the H-alpha telescopes at a solar activity target will also point the other ATM telescopes to the same target. The amount of H-alpha emission recorded will be correlated with the intensity of other emissions.

Film and TV pictures will be obtained. Removal of the exposed film from the telescope will involve extravehicular activity (EVA).

ATM Extreme Ultraviolet (XUV) Spectroheliograph (S082A)

The S082A telescope and camera system will photograph the Sun in selected ultraviolet wavelengths between 150 Angstroms (Å) and 650 Å (1 Å = 10^{-10} meter). This experiment will photograph the entire solar disc within the wavelengths indicated and will provide information on the presence of chemical elements in the Sun's atmosphere. The exposed film will be retrieved by astronaut EVA.

ATM Extreme Ultraviolet (XUV) Spectrograph (S082B)

The S082B telescope with camera and TV capability will photograph the Sun at wavelengths between 970 Å and 3940 Å. The spectrograph is used to record the spectrum of ultraviolet emission such as flares or filaments from a small individual feature on the solar disc. Real-time TV is used by the crew to monitor performance of the telescope and is also transmitted to the ground and recorded. The exposed film will be retrieved by astronaut EVA.

ATM Ultraviolet (UV) Scanning Polychromator Spectroheliometer (S055)

This instrument is mounted in the ATM canister and gathers ultraviolet data from the Sun in the 300 to 1350 Å region. It consists of seven detectors, each tuned to accept light waves within a narrow wavelength band. The presence of light in each band gives an indication of the presence of oxygen, magnesium, carbon, and some rare elements in the Sun's atmosphere. It is possible to ascertain the relative distribution of these elements in quiet and active regions of the Sun by coordinating data from this experiment with solar activity data from the companion ATM H-alpha telescope.

No film is used in this experiment. The data is recorded electronically on magnetic tape for later transmission to the ground.

ATM X-Ray Spectrographic Telescope (S054)

This instrument will take X-ray photographs of the solar disc in six wavelengths from 2 Å to 60 Å. Since X-ray penetration of materials is a function of the wavelength of the X-ray and of the material density, filters made of various materials of various thickness can be used to select the wavelength to be photographed. By this method X-ray spectra can be developed for selected active regions on the Sun.

Film is the primary form of data from this experiment. It will contain the X-ray images and the spectra. The film will be removed from the telescope by astronaut EVA. A real-time TV presentation of the X-ray pictures of the Sun will be available on the monitors of the ATM control and display panel during the experiment.

ATM X-Ray Telescope (S056)

This X-ray experiment has two goals. The first is to take X-ray pictures of the entire solar disc in six spectral bands from 5 Å to 33 Å. The second goal is to measure the total X-ray emission from the Sun, as a function of time, in each of 10 spectral bands between 2 Å and 20 Å. This measurement of X-ray emission will be recorded to give a time history of X-ray activity in each wavelength, and is an excellent means of indicating solar activity.

The X-ray pictures are recorded on film and retrieved by astronaut EVA. The data from the X-ray measurement is recorded on magnetic tape.

ATM White Light Coronagraph (S052)

This experiment views the Sun's corona out to four million miles from the Sun's surface. In order to photograph the faint light so far away from the Sun, a mask is used to very precisely obscure the intensely bright solar disc. In Fig. 21, which illustrates the masking of the solar disc, the corona can be traced as far out as two million miles from the Sun.

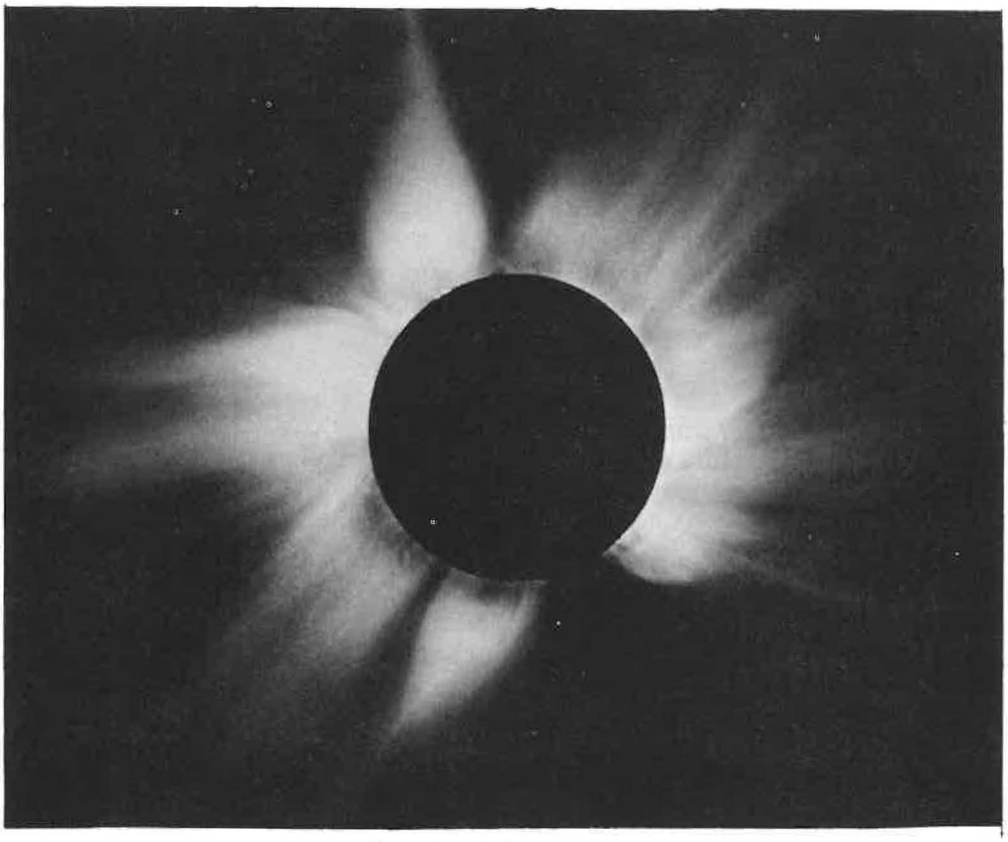


Fig. 21 Solar Corona

By taking photographs as fast as one every 13 seconds, the rapidly moving material in the corona can be photographed as it leaves the Sun and travels far out into space. As the Sun rotates and sunspots are carried into the region being studied, the coronal activity may be affected. The relationship of this effect with other solar activity, observed by other experiments, can be determined. A low light-level TV camera will allow TV viewing of the corona.

Data is recorded on 35 mm film to be retrieved during EVA.

X-Ray/UV Solar Photography (S020)

This is the only solar experiment not mounted on the Apollo Telescope Mount. It is mounted in an airlock in the wall of the OWS facing the Sun. The experiment produces spectrum plots of selected activities at selected areas on the Sun. Plots can be made of a solar explosion or flare, and analysis of these plots will yield temperature, density, and composition of the gas involved in the activity. The recording range is 10 Å to 200 Å.

The data will be recorded on film and returned to Earth for processing and analysis.

Nuclear Emulsion Experiment (S009)

The objectives of this experiment are to study the charge spectrum of cosmic rays and measure the relative abundance of heavy nuclei and unknown rare particles. Cosmic rays consist of the nuclei of chemical elements, and are considered to originate in thermonuclear reactions in certain stars.

The instrument consists of two stacks of emulsion strips. The emulsion is silver halide crystals embedded in gelatin. When a particle strikes the emulsion, it activates the sensitive silver crystals in its path similar to the way light affects an ordinary photographic emulsion. Upon development of the emulsion, a row of black silver grains and "blobs" marks the path of the particle. By measuring the number, thickness, direction, and length of the tracks, the energy and charge of the cosmic rays can be determined and information can be obtained about the physical conditions at formation of the nuclei. Figure 22 is a typical example of a nucleus track in an emulsion stack and shows four segments from the trace.

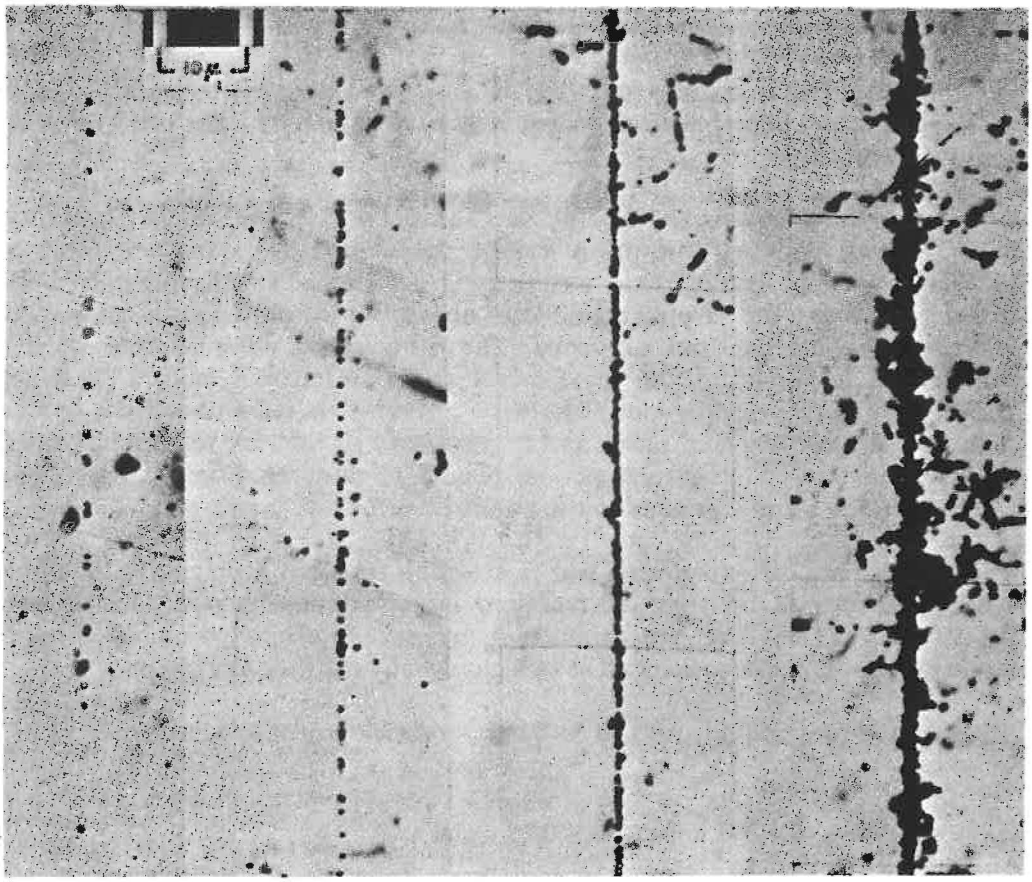


Fig. 22 S009 Atomic Nuclei Track

The stacks of emulsion are arranged like an open book, mounted inside the MDA and can be adjusted to point only to outer space. The "book" is closed when Skylab is in high radiation areas or high latitudes where changes in the direction of the Earth's magnetic field would compromise the results obtained. The emulsion will be exposed for about 240 hours during the first manned mission. The emulsion stacks will be returned to Earth with the first crew for separation, development, and analysis.

Ultraviolet Stellar Astronomy (S019)

The objective of this experiment is to obtain ultraviolet spectra from stars. The instrument consists of a reflecting telescope and a 35 mm camera. The telescope is mounted on an airlock in the side of the Orbital Workshop. A movable mirror, part of the telescope, can be adjusted to focus a selected portion of the sky onto the telescope, and a prism is used to spread the light into a spectrum. A group of stars can be photographed at one time. The spectral information obtained will provide insight into the origin and composition of the stars, nebulae, and interstellar dust. The temperature, pressure, and size of a star's atmosphere can also be determined from the information contained in the photographs.

Ultraviolet Airglow Horizon Photography (S063)

Experiment S063 is actually two separate experiments which share the same equipment. One experiment is called ozone photography, the other twilight airglow photography.

The ozone above the Earth's atmosphere absorbs part of the sunlight falling on Earth. The amount of absorption can be determined by taking two series of simultaneous photographs. One series, using a 35 mm camera with ultraviolet filters will record the varying amounts of absorption of ultraviolet illumination, indicating varying densities of ozone. The other series using another 35 mm camera will be aimed at the same target as the ultraviolet camera. This will photograph, in wavelengths not absorbed by ozone, the reflections from ground features such as water and snow, and from clouds, so that the varying brightness in the ultraviolet photographs can be related to the variations in reflectivity recorded in the second series of photographs.

The twilight airglow experiment will photograph the glow occurring in the upper atmosphere caused by chemical reactions in the ozone, oxygen, nitrogen, and other gases when they are stimulated by the Sun's radiation. The upper atmosphere will be photographed at twilight against the dark sky of space.

The exposed film will be returned to Earth for development and analysis.

Gegenschein/Zodiacal Light (S073)

The objective of this experiment is to measure the brightness of the visible background light seen above Earth's atmosphere.

Gegenschein is a faint nebulous light opposite the Sun. It is so faint that it can only be observed in the absence of moonlight. Astronomers generally believe that this light is the result of the reflection of sunlight from interplanetary material located in a region outside Earth's orbit.

Zodiacal light is a band of light in the night sky concentrated along the ecliptic (the plane in which Earth orbits the Sun). It is seen in the west after twilight and in the east before dawn. It also is believed to be caused by the reflection of sunlight from interplanetary material between the Sun and Earth.

The S073 experiment will measure the brightness and polarization of these light sources using a camera and a telescope with a photometer for measuring light levels. The camera records the field of view being scanned by the telescope. The light level readings are recorded on magnetic tape. Both film and tape will be returned to Earth for analysis.

Particle Collection (S149)

The objective of this experiment is to collect material from interplanetary dust particles to determine the quantities and sizes of minute particles (micrometeoroids) in near-Earth space and to learn something of their composition and structure. Specially prepared sample collection surfaces will be extended from Skylab. When a micrometeoroid strikes one of these surfaces it will leave a crater. The characteristics (mass, size, and velocity) of these particles can be calculated from analysis of the craters.

Galactic X-Ray Mapping (S150)

The purpose of this experiment is to survey the sky for faint X-ray sources. The experiment will determine whether there is a continuous background of X-rays or whether X-rays emanate from discrete sources. The equipment consists of a proportional counter that counts the number of times it detects radiation at varying levels between 200 and 12,000 electron volts. The experiment is mounted in the Instrument Unit of each Saturn IB booster that launches a manned Command and Service Module to Skylab. The information obtained is recorded and transmitted to Earth.

Ultraviolet Panorama (S183)

This experiment has as its objectives the measurement of the brightness, in the ultraviolet range, of a number of stars and bright galaxies. Observation of this brightness is impossible on Earth due to the absorption by Earth's atmosphere.

The brightness of more than 1000 stars at various locations in our galaxy will be measured, and this information will be used as a basis for future studies of the spiral arms of this galaxy.

Biomedical Science

The Skylab biomedical program is a study of normal, healthy men and their reactions in an environment where gravity, one of Earth's key environments, has been removed. From this study a great deal can be learned about gravity's importance to man's physiological functions.

Previous studies of man exposed to zero gravity observed a consistent loss of body fluid; a small, but repeated, loss in bone calcium and muscle mass; and a reduction in the ability of blood vessels to actively distribute blood to the various parts of the body following return to an Earth gravity condition. These effects disappeared a few days after returning to Earth and so far have shown no consistent relationship with the time spent in zero gravity. Similar effects have been observed in individuals confined to prolonged bed rest on Earth.

Skylab will allow an evaluation of these and other phenomena under prolonged zero gravity conditions using more rigorous evaluation techniques. Specifically, the biomedical experiment program will consist of the following investigations:

- Nutrition and musculoskeletal experiments to investigate the effect of gravity on nutritional requirements and the attendant gain or loss of the body's biochemical constituents;
- Studies of the role of gravity in man's metabolic effectiveness in doing mechanical work;
- Cardiovascular studies to determine the effects of long exposure to zero gravity on the heart and blood vessels and measure the response of the circulatory system to various workloads;
- Hematology and immunology experiments to investigate the behavior of the blood cells, body fluid compartments, body immunity, etc, when gravity is absent;
- Studies of the role of gravity on man's psychomotor efficiency and the performance of useful tasks;
- A study of the responses of the human vestibular system in the absence of gravity;

- Circadian rhythm studies to determine whether the normal rhythms of sleep and wakefulness, and many other less obvious effects, are influenced by a zero gravity environment and the more rapid day/night cycle (1½ hr vs 24 hr); and

- A study of the biological clock in men, mice, and fruit flies.

The specific experiments are discussed in the following paragraphs.

Mineral Balance (M071)

The objective of this experiment is to determine if the absence of gravity on the muscle and skeletal systems of the body results in the gain or loss of pertinent biochemical constituents. These constituents are water, calcium, phosphorus, magnesium, sodium, potassium, nitrogen, urea, hydroxyproline, creatinine, and chloride. Continuous losses of calcium and nitrogen can, for example, result in impairment of skeletal and muscle systems and the formation of kidney stones.

The experiment will be accomplished in three phases: (1) preflight from 23 days to 2 days before launch, (2) during flight, and (3) for 18 consecutive days beginning immediately after splashdown. The functions to be performed and the controls to be exercised are as follows:

- Body weight (or mass) will be measured once daily immediately after the first urine voiding following the sleep period.

- A standard diet of defined composition will be used since the composition of the subject's diet must be known and carefully controlled. Before flight each crewman will use this diet to establish his normal (or baseline) data, reflecting his individual metabolic balance.

- Fluid can be taken as desired but all intake will be recorded. This includes fluid used for food reconstitution.

- All urine, feces, and vomitus if any, will be collected pre- and postflight and preserved for analysis. In flight, the amount of daily urine output from each crewman will be determined and a measured sample taken, frozen, and stored for return as experiment data. All feces and vomitus passed will be collected and their mass will be measured. The samples will then be dried and stored for return as experiment data.

- Periodic blood samples, pre- and postflight, will be taken and the concentration of selected metabolic constituents determined.

The biomedical samples, together with the men's comments recorded in the log books, will be returned to Earth at the end of each manned mission.

Bioassay of Body Fluids (M073)

This experiment is closely related to M071 and all of the data generated from M071 is required for M073.

The objective of this experiment is to evaluate the endocrinological effects on man resulting from long exposure to zero gravity. Although many external influences contribute to the environment of the human organism, the environment of its basic unit, the living cell, is wholly internal to the body. Since changes in extracellular fluid produce changes in the composition of the intracellular fluid, it is essential to the normal function of cells that the constancy of the extracellular fluid be maintained. This is achieved by the close interaction of several organ systems, the kidneys holding a predominant role. The kidneys are thus viewed as an organ that not only removes metabolic wastes, but actually performs highly important stabilizing functions by adjusting plasma volume and composition.

The important control mechanisms that govern plasma volume and composition and the complex interactions of these metabolic and endocrine controls are not well understood. In man's constantly changing environment, there is a narrow margin of protective safety between normal, hypo- and hyper-function of these mechanisms. Evidence now exists to suggest that derangements of these normal mechanisms may play a significant role in man's adaptation to stress.

In performing this experiment, the following elements in blood (pre- and postflight only) and urine will be evaluated: adrenocorticotrophic hormone (ACTH), 17-hydroxycorticosterone (Cortisol), angiotensin II, renin, aldosterone, antidiuretic hormone (ADH), epinephrine, norepinephrine, urine electrolytes (sodium and potassium), urine and plasma osmolality, extracellular fluid volume, total body water, serum thyrocalcitonin, parathyroid hormone, serum thyroxine.

Specimen Mass Measurement (M074)

The objectives of this experiment are to demonstrate the feasibility of determining mass in zero gravity, and to validate the theoretical behavior of a mass measurement device and while so doing actually measure the mass of biomedical specimens for the other medical experiments.

The conventional methods of measuring the mass (or weight) of objects do not work in the absence of gravity. The Skylab concept depends on timing the oscillating frequency of a linear spring-mass pendulum system. The mass to be measured uniquely determines the oscillating frequency (cycles per second) of the device, and by measuring this frequency, the mass of an object can be determined.

Body Mass Measurement (M172)

The objective of this experiment is to demonstrate the feasibility of body mass measurements in zero gravity and to provide body mass data in support of other experiments. The principle of this experiment is the same as for experiment M074 (Specimen Mass Measurement); however, this device is large enough to hold a man.

Bone Mineral Measurement (M078)

This experiment will determine the occurrence and extent of zero-gravity-induced bone mineral changes by measuring the bone mass of the left heel and forearm (radius) before and after Skylab flight.

The stimulus of normal chemical activity in the bones is a function of the pulling force exerted on the bone by the attached muscles and the force exerted on the skeletal system by gravity. Both forces are altered during complete bed rest and by lack of gravity. Bone mineral losses, for a long time associated with long term bed rest, were experienced in an inconsistent pattern in Gemini and Apollo missions. Because present data is inconclusive, Skylab represents an important opportunity to improve our understanding of this phenomenon.

Data will be taken pre- and postflight on the flight crew and three control group members. The experiment will utilize a scanning device containing an iodine-125 photon source. The degree of photon absorption is measured by an X-ray detector and multichannel analyzer.

Lower Body Negative Pressure (LBNP) (M092)

This experiment will investigate the relationship between the zero gravity environment and cardiovascular deconditioning. Observations will be made in the absence of gravity and will be compared with the same phenomenon as it has been observed during and following extended periods of bed rest.

A characteristic of cardiovascular deconditioning is the partial failure of the blood vessels resulting in excessive pooling of the blood in the legs when a person assumes an erect posture in a gravity field. When excessive blood pooling takes place, the rate of blood flow through the heart and lungs is reduced causing the pulse pressure (difference between peak or systolic and valley or diastolic blood pressure) to be less, and the average pressure to be too low resulting in reduced flow to the brain. Dizziness and fainting are then likely when the person stands.

The LBNP experiment intentionally imposes a slight suction to the lower half of the body to test how the cardiovascular system (blood circulation system) reacts to a controlled amount of blood pooling during weightlessness and how quickly and how severely the condition progresses.

The inflight LBNP apparatus consists of three units: (1) a cylindrical tank with a waist seal into which the subject puts his legs (The interior pressure of the tank can be reduced and maintained at 1 psi below ambient cabin pressure); (2) a leg volume measuring system that records the circumference of each leg at the calf muscle; and (3) an automatic blood pressure measuring system with an automatically inflatable arm cuff, a microphone for detecting blood flow, and the ability to record systolic and diastolic blood pressure. The experiment also uses the vectorcardiogram equipment from M093 and the body temperature sensors from M171.

The experiment is performed every three days on each crew member by one of the other men. The information obtained is stored on magnetic tape or telemetered directly to Earth, depending on the availability of a ground station.

Figure 23 shows one crewman as the subject in the LBNP device while a second crewman controls the experiment. Also visible are the sensors (attached to the torso and ear of the crewman in the LBNPD) that monitor temperature and heart rate.

Vectorcardiogram (M093)

The aim of this experiment is to measure the vectorcardiographic potentials of each crewman periodically during the mission so that the space-environment-induced changes in the heart function can be detected and compared with changes caused by ground-based physiological stressors.

The technique of vectorcardiography yields more information than the conventional electrocardiogram. In addition to detecting the electrical activity of the heart, which is common to both methods, the vectorcardiographic method of processing signals from the electrodes enables the investigator to directly infer the position of the heart inside the chest and its change in position at various instants during the heartbeat cycle. This more precise information is necessary in analyzing heart functions in weightlessness. The measurements will be made before and after the ergometer exercise of M171 and the lower body negative pressure experiment of M092.

The equipment consists of eight electrodes, attached to the subject immediately before the experiment, and the associated electronic equipment which includes preamplifiers and a signal conversion network. The data is recorded on tape and telemetered to the ground during periods of ground station contact.

Metabolic Activity (M171)

The primary objective of this experiment is to determine the importance of gravity to man's effectiveness in doing mechanical work. The experiment consists of measuring the metabolic activity (oxygen consumption, carbon dioxide production, respiration, blood pressure, heart rate) associated with identical tasks performed on the ground and in space.

The equipment consists of a metabolic analyzer that measures oxygen consumption, carbon dioxide production and the total volume of "air" inspired or expired in one minute, and an ergometer, a bicycle-type device designed to allow the subject to perform controlled and measured exercises in zero gravity using either his hands or his feet. This ergometer can be used either to produce a desired heart rate by varying the workload or to present a constant workload (Fig. 24).

The experiment will be conducted on each crewman five times in the 28-day mission and eight times in each 56-day mission.

Cytogenetic Studies of the Blood (M111)

The objectives of this experiment are to determine the frequency of chromosome aberration in the crew by means of pre- and postflight studies of blood samples, and to determine if these aberrations can be related to the zero gravity environment.

As carriers of genes, chromosomes provide the basis for control of most of the biochemical activities within an organism. Although chromosomes possess a definite organization, they are susceptible to change. Through various means, such as radiation and chemical activity, their normal structure may be disrupted. Because chromosomes and their genes are so vital to the proper functioning of the body, it is pertinent to determine if factors such as weightlessness and radiation cause an increase in chromosomal aberration frequencies.

Chromosome analyses were done for all of the Gemini missions (except Gemini VIII) under the operational medical program. Significant, though slight, increases in some types of chromosomal aberrations were seen following some of the missions. This could not be correlated with mission duration, EVA, isotope injection of the crews, or other obvious flight parameters. Pre- and postflight blood samples of Skylab crews can assist in increasing our knowledge of this phenomenon.

Man's Immunity (M112)

The objective of this experiment is to assay the changes in man's cell chemistry that result from prolonged exposure to zero gravity. Relating zero gravity changes to Earth gravity cell phenomena can increase our knowledge of immunity mechanisms.

This experiment measures items that contribute to man's ability to combat infections and repair injured tissues, and to observe their effectiveness after exposure to weightlessness, ionizing radiation, and other space environment phenomena.

Before flight, crew members will be observed to establish their normal metabolism. Immediately after flight, similar information will be obtained for comparison with preflight information.

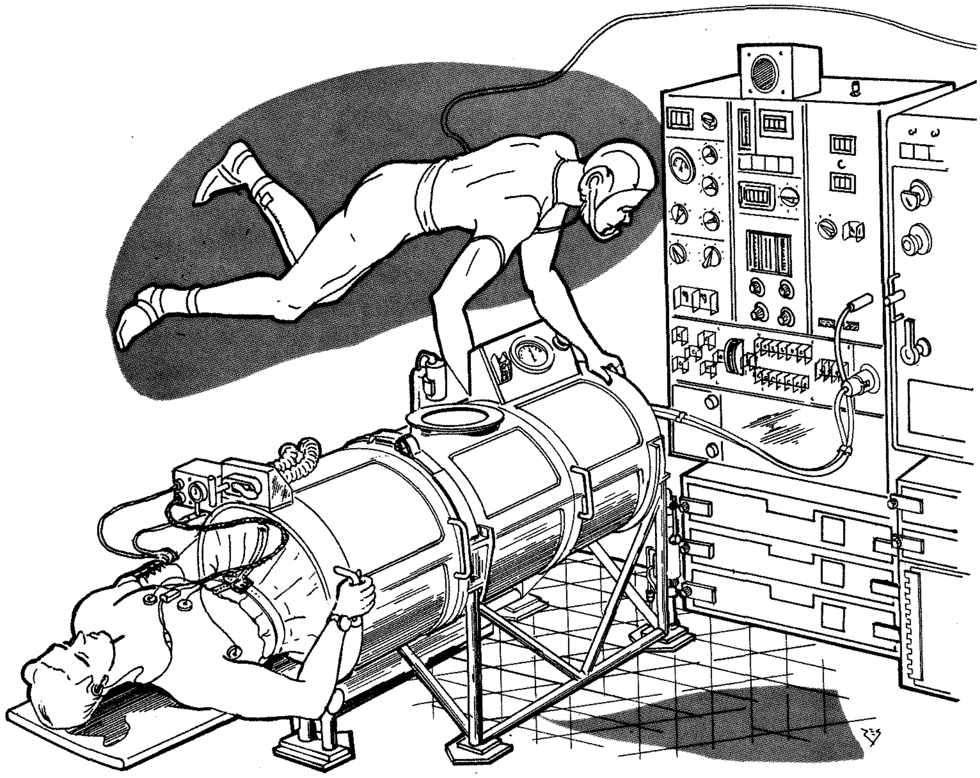


Fig. 23 Lower Body Negative Pressure Device

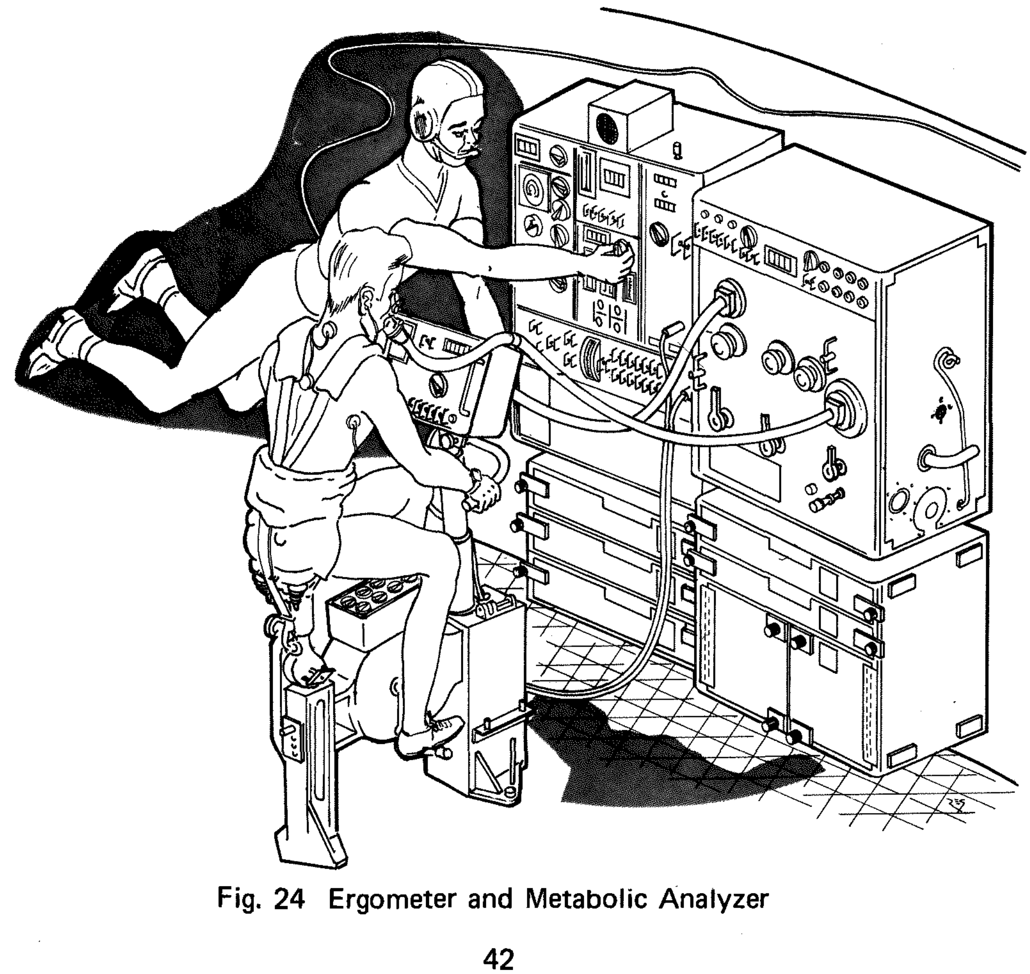


Fig. 24 Ergometer and Metabolic Analyzer

Blood Volume and Cell Life Span (M113)

The objective of this experiment is to determine the effect of zero gravity on the plasma volume and red blood cell population with particular attention paid to changes in red cell mass, red cell destruction, red cell life span, and red cell production rate. Data from blood samples taken before flight will be compared to data from samples taken after flight.

The red blood cells (RBC) of the circulatory system provide the means of transporting oxygen from the lungs to all parts of the body. The oxygen carrying capacity of this system is proportional to the amount of RBC available. Decreases in RBC mass force the system to compensate by increasing the heart rate, breathing rate, etc., simply to maintain normal oxygen flow. As a result the ability of the cardiovascular system to meet peak oxygen demands is reduced.

Radioisotope studies on Gemini V and VII showed decreases in red blood cell mass and shortened life spans of red blood cells in three of the four crewmen. The information obtained from Skylab will be correlated with the Gemini data in order to better understand RBC behavior in the absence of gravity.

Red Blood Cell Metabolism (M114)

The objective of this experiment is to determine the effect of gravity on the membrane and metabolism of the human red blood cell.

In order to effectively perform its function of transporting oxygen, the red blood cell requires energy which it obtains by processing glucose. The means by which the glucose penetrates the cell membrane and enters the cell is not known. By performing an analysis of red blood cells that have spent a significant portion of their lives in a system in zero gravity, more information will be gained on the glucose transfer process, the structure of the cell membrane, the metabolic process within the cell, and the dependency of these on gravity.

Human Vestibular Function (M131)

The purpose of this experiment is to examine the effect of weightlessness on the vestibular system, specifically man's sensitivity and susceptibility to motion and rotation, and his perception of orientation.

The equipment for this experiment consists of:

- A chair that can be rotated by a motor at its base or, not being rotated, can tilt forward, backward, or to either side; and the controls necessary for using it;

- A test goggle containing an illuminated line that can be adjusted by the man to what he considers to be the vertical or horizontal position;

- A reference sphere with a magnetic indicator rod by which the astronaut can, without looking, indicate what he considers his body orientation to be.

Effects of Zero Gravity on Single Human Cells (S015)

The purpose of this experiment is to measure the functions of human kidney cells while they are subjected to weightlessness. In order to determine what effect gravity has on individual cells, a complete survey of cellular structure and biochemical function is necessary. Previous studies have been performed in high gravity fields and in Earth's gravity, but there is as yet no knowledge of subgravity effects.

To perform the experiment, cells will be examined with time-lapse microscope photography at magnifications of 40X and 20X. Two separate groups of cell cultures will be observed in space for 4- and 10-day periods. After several biochemical experiments are performed, the cells will be preserved and returned for further chemical tests on Earth. The experiment will measure DNA, RNA, and lipid content of the cells, and enzyme activity.

These zero-g studies will be combined with the same measurements in Earth gravity and 200 to 300 times Earth gravity in order to complete a gravity profile of the response of human cells to gravity fields.

Circadian Rhythm of Pocket Mice (S071)

The purpose of this experiment is to find out whether the daily physiological rhythms of a mammal are altered by the space environment.

If the stability (precision) of the period of physiological rhythms changes significantly in space, then there is a strong indication that biorhythms of animals on Earth are timed by some factor or force that is absent or significantly different in space. On the other hand if the pocket mice in space continue their terrestrial biorhythms, then we can conclude that space conditions impose no significant new stress on the basic biological clock mechanism of mice or men.

Six pocket mice will be enclosed in a dark, constant temperature, atmospheric pressure chamber for approximately three weeks immediately before flight. Continuous measurements will be made of their body temperature, heart rate, and activity level in order to establish the natural period, phase, and stability of the rhythms. The experiment chamber will then be put in orbit on Skylab and the same measurements continued throughout flight.

This experiment is mounted inside the Service Module in the manned launches.

Circadian Rhythm of the Vinegar Gnat (S072)

The goal of this experiment is to find out whether the daily emerging cycle of the vinegar gnat (drosophila) pupae is the same in space as on the Earth.

Extensive experiments have shown that even though gnats in the pupae stage develop at different rates depending on temperature, their emergence from the pupae as adult gnats is dependent on an internal triggering signal that is somehow timed to occur at an exactly fixed period of time after a flash of light, and at the same daily time thereafter, regardless of the temperature. This experiment will measure the emergence times of pupae in two groups, one at 16°C and the other at 26°C, to find out whether the space environment changes the mechanism that keeps the rhythm constant despite changes in temperature. Each of the two temperature groups will be divided in half so that they can be initiated by the synchronizing flash at two different times, 12 hours apart. If the delayed group shows the same rhythms of emergence as the earlier group, then it is likely that no external factor contributes to the rhythm behavior and that the rhythms are internally synchronized.

This experiment and the circadian rhythm of pocket mice (S071), test the stability of biorhythms in two completely different kinds of living systems—insects and mammals. If both rhythm systems become disrupted during the Skylab mission, then it can be said that the space environment affects some kind of basic process common to both rhythm mechanisms, and it is likely that man's biological clock is similarly dependent on Earth's environment.

Sleep Monitoring (M133) and Time-and-Motion Study (M151)

Data obtained in the conduct of these two experiments in the Space Applications area of this chapter will provide information on the role of gravity in man's neurophysiological performance and psychomotor efficiency.

Earth Applications

Remote sensing of Earth from space has the potential of being a fundamental technique in effective use and conservation of natural resources, and in better understanding and managing interacting influences between man and these natural resources.

Photography from spacecraft in Earth orbit in the visible and near-infrared wavelengths has proven valuable for mapping geographic and weather features over large areas of the Earth. Systematic application of remote sensing techniques using additional wavelengths may extend the usefulness of this capability to mapping of Earth resources and land uses. Resources amenable to this type of study include crop and forestry cover, health of vegetation, types of soil, water storage in snow pack, surface or near-surface mineral deposits, sea surface temperature, the location of likely feeding areas for fish, etc.

Development of remote sensing techniques in extended spectral ranges, at altitudes up to 60,000 feet, already is a part of the NASA aircraft program. Aerial reconnaissance of ground truth sites has and is being conducted to test measuring techniques, to validate interpretive techniques and to ascertain the dependability of recognizable spectral signatures. Development has reached the point where remote sensing has been used operationally to assist in pinpointing forest fires through dense smoke cover and mapping corn blight damage.

Space tests of remote sensing techniques have also been conducted during the Gemini and Apollo missions. Several thousand high quality photographs obtained by the Gemini crews have been effectively used in many disciplines. Apollo missions added the use of haze filters, and demonstrated photography in the visible and near-infrared wavelengths, overlap photography for stereo viewing, and photography of ground test sites.

The Skylab Earth resources experiment package (EREP) is the most recent step in this important aspect of understanding and managing the Earth/man relationship. EREP will improve on the Apollo visible light and infrared photography and will, in addition, include electronic infrared spectrography and microwave radiometry surveys.

The photography will greatly improve resolution of Earth resources phenomena by virtue of simultaneous exposures using six matched cameras and by precise photometry that can provide more accurate knowledge of light intensity levels in each survey photograph. The infrared spectrography survey will operate in wavelengths not recordable on photographic film and will provide data from which recognizable spectral signatures of the phenomena observed can be plotted. By simultaneously operating in frequencies transmitted by the atmosphere and those attenuated by atmospheric moisture, atmospheric density profiles can be generated.

The microwave radiometry equipment, because of its low sensitivity to atmospheric moisture, will provide an all-weather source of information on surface moisture and temperature and on vegetation distribution. Microwave radiometry over the oceans will provide information on wind and sea conditions on a global scale.

The EREP experiments are described in more detail in the following paragraphs.

Multispectral Photography Facility (S190)

The multispectral photography facility has been designed to photograph regions of the Earth's surface, including oceans, in a range of wavelengths from infrared through the visible. The facility consists of six cameras that simultaneously photograph the same area, each viewing in a different wavelength. Because the cameras are accurately matched, the six separate photographs will have good registration with respect to one another; that is, features seen in one photograph can be easily aligned with the same features in the photographs from the other cameras.

The advantage of multispectral photography is that various conditions of interest such as soil moisture, types of vegetation, or health of the vegetation produce different spectral responses or signatures. By studying features in various ranges of wavelength, it is anticipated that information about such conditions can be derived from the photographs.

A viewfinder is provided to allow the astronaut to view the region being photographed, and where his observations indicate the necessity, to select picture sequences.

Infrared Spectrometer (S191)

The primary goal of this experiment is to evaluate the usefulness of viewing Earth resources from orbital altitudes in the visible through near-infrared and far-infrared spectral regions. The reliability of identification of Earth phenomena from orbital altitudes will be checked by comparing these results with concurrent measurements from aircraft and on the ground. This technique has the potential for monitoring from space the extent and health of surface vegetation without the need for direct examination of individual plants. Geological information and precision sea surface temperature measurements can also be obtained.

The spectrometer has pointing and tracking capabilities within a 20-degree cone (from vertical). The astronaut will use the viewfinder/tracker to find the target that usually will be in his field of view for less than a minute. At the start of each scan, the scene in the viewfinder will be photographed on a small camera attached to the viewfinder. The astronaut will select secondary ground targets if the primary site is obscured by cloud cover, and targets of opportunity as they become available.

The primary data will be recorded on magnetic tape together with data from other sensors in the Earth resources experiment package. The magnetic tape and recorders will be returned during each crew rotation.

Multispectral Scanner (S192)

The primary goal of experiment S192 is to evaluate multispectral techniques (developed in aircraft programs) for use in remote sensing of Earth resources from space. Specifically, experiments in signature identification and mapping will be performed using ground-truth targets in agriculture, forestry, geology, hydrology, and oceanography.

Multispectral scanners have been flown in aircraft for several years. Promising results have been obtained for identification and mapping of vegetation and surface soils. Some progress has also been made in using the remotely sensed data for assessing the health of vegetation. Achievements in this area include crop identification and inventory, and soil and geologic mapping based on the unique signatures of certain crops.

The spectral range covered by this scanner overlaps the multispectral cameras (S190) and the IR spectrometer (S191). This will permit a useful cross-check of results obtained from all three systems. The IR spectrometer may also provide atmospheric density profiles that would be useful in correcting for atmospheric attenuation of scanner data.

The primary data will be recorded on magnetic tape.

Microwave Radiometer/Scatterometer (S193)

The microwave radiometer/scatterometer complements the infrared spectrometer and multiband scanner experiments (S191 and S192). For agricultural purposes, for instance, infrared remote sensing devices are very suitable for vegetation identification through the clear sky; however, it is most probable that clouds will exist in scattered areas in the sky and thus degrade the measurement results and interrupt the continuity of coverage. The effect of clouds on microwave propagation is less significant and, in general, can be corrected by simultaneous use of microwaves of different frequencies.

The microwave radiometer/scatterometer experiment combines an active radar scatterometer and a passive radiometer. The radar backscattering measurement gives a combined measure of terrestrial dielectric properties and surface roughness, and the passive microwave emission gives a combined measure of the dielectric properties, roughness, and brightness temperature of the terrestrial surface.

Using this data the microwave radiometer/scatterometer experiment can determine the roughness and temperature of the terrestrial surface when the dielectric properties of the surface are known. Since the surface dielectric properties vary a great deal according to moisture content and vegetation, "ground-truth" measurements of dielectric properties at strategically selected sites will be employed.

All data will be recorded on magnetic tape.

L-Band Microwave Radiometer (S194)

The purpose of this experiment is to augment the radiometer part of the preceding experiment (S193). By simultaneously operating at a different frequency, corrections can be made in the radiometer data to compensate for cloud effects.

Space Applications

The experiments described in this section are related primarily to improving manned operations in space and to space technology in contrast to the man/Earth interrelationship activities described in preceding sections of this chapter.

From the manned operation of Skylab, much information will be obtained on the suitability, or unsuitability, of the living conditions provided for the crew. The crews' comments on the size and shape, ease of use, comfort, and appearance of the spacecraft will be obtained in order to provide a store of information on which the "architecture" of future long duration, manned, space vehicles can be based. A valuable part of these observations will be the crews' subjective comments. Their likes and dislikes are as valuable as the discrete measurements they make. An example of this, and one which may profoundly influence the architecture of future vehicles, is the reported sense of "roominess" that weightlessness, with its capability of multidirectional orientation, appears to induce.

Zero gravity introduces new approaches to astronaut mobility. Within the spacecraft, movement from one area to another can be achieved by drifting. However, this must be done carefully to avoid injury. Outside the spacecraft the same form of movement is possible but, at best, is inconvenient, and without a restraining tether is dangerous. Movement along the outside of the spacecraft is possible by using handholds, but movement through space to another vehicle requires more sophisticated methods. Two Skylab experiments are planned to test types of astronaut maneuvering equipment within the experiment compartment in the workshop.

Closely associated with the freedom of travel afforded by zero gravity is the sensitivity of the orbiting spacecraft to disturbances caused by crew activity inside it. Skylab experiments will evaluate the magnitude of this effect.

Manufacturing techniques not possible on Earth may be possible in zero gravity. Casting of spheres, growth of crystal structures, development of foamed high strength materials are some of the space manufacturing technology concepts to be studied in Skylab. It is hoped that these experiments will lead to practical uses of space for processing of a variety of materials, from crystals to pharmaceuticals to high strength structures.

At the orbital altitude of Skylab, the radiation environment differs greatly from the environment on Earth. The radiation approaching Earth is captured by Earth's magnetic field and forms belts whose inner surface is some 250 to 300 miles above Earth. These belts are known as the Van Allen Belts. Over one part of the Earth's surface traversed by Skylab (the south Atlantic), this belt dips low enough for Skylab to pass through. The radiation levels in this South Atlantic Anomaly must be measured, and the cumulative effects determined.

Each of the space application experiments is described below.

Habitability/Crew Quarters (M487)

The objectives of this study are to evaluate the features of Skylab's living quarters, provisions, and support facilities as they affect the crew's comfort, safety, and operating efficiency.

Equipment, procedures, and habitat design concepts derived from experience on Earth and from previous short duration orbital flight may require modification. This evaluation is a multidisciplinary set of systematic observations, and is a test and validation of design concepts and hardware features.

This experiment relies heavily on data obtained from the biomedical science experiments. The following aspects of system design and operation will be studied.

- Physical environment (temperature, humidity, light, noise)
- Architecture (volume and layout of working and living areas)
- Mobility aids and personal restraints (translation, worksite support, sleep stations)
- Food and water (storage, preparation, quality)
- Personal garments (comfort, durability, design)
- Personal hygiene (cleansing, grooming, collection and disposal of body waste)
- Housekeeping (habitat cleansing, waste control and disposal)
- Off-duty activities (exercise facilities, individual and group recreation, privacy features)

Astronaut Maneuvering Equipment (M509)

The object of this experiment is to conduct an in-orbit verification of the usefulness of various maneuvering techniques and equipments in assisting astronauts to perform tasks that are representative of future EVA requirements.

The concept of powered astronaut maneuvering is fundamental to the development of an effective EVA capability which, in turn, is considered to be a major supporting element in future manned space flights. Specifically, NASA study of future manned space flight operational requirements indicated that EVA can be expected to play a major role in such areas as space rescue, inspection and repair of parent and satellite spacecraft, personnel and cargo transport, and space structure erection. The addition of maneuvering aids to such EVA tasks is expected to reduce crew fatigue and stress, cut time requirements, offset pressure suit mobility limitations, and facilitate attitude orientation and stabilization.

The astronaut maneuvering equipment of this experiment consists of two jet-powered aids for maneuvering in a zero gravity space environment. These are a back-mounted hand-controlled unit called the automatically stabilized maneuvering unit (ASMU or backpack) and a hand-held maneuvering unit (HHMU). Both systems employ the same rechargeable/replaceable high pressure nitrogen propellant tank. Figure 25 shows an artist's concept of an astronaut using the backpack maneuvering unit inside the Skylab workshop.

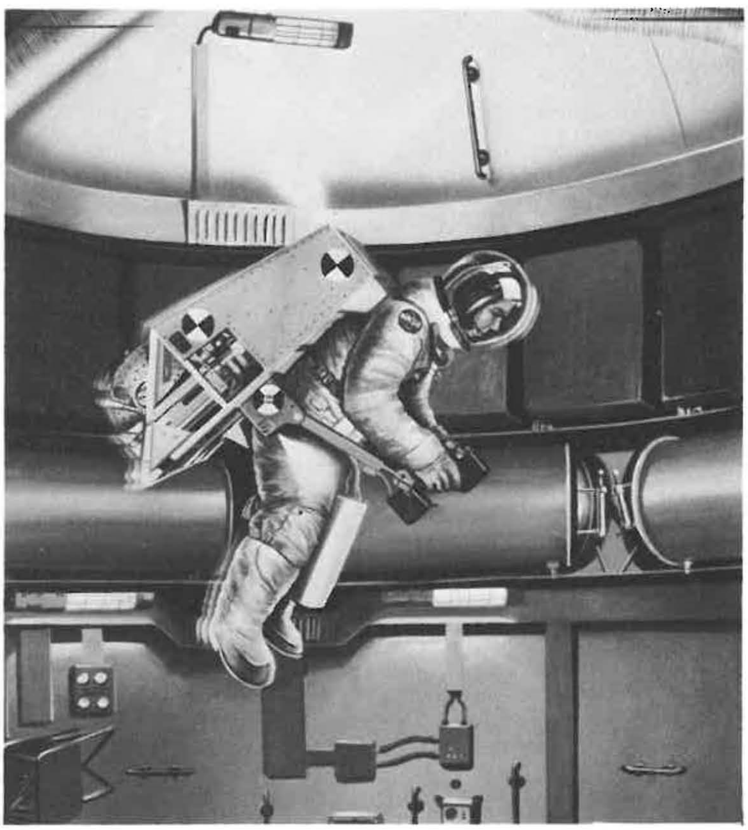


Fig. 25 Astronaut Maneuvering Unit

The ASMU is maneuvered by means of 14 fixed thrusters located in various positions on the backpack. The thrusters are controlled by two hand-controllers mounted on arms extending from the backpack. The left hand controls translation forward, backward, up, down and sideways, and the right hand, using an aircraft-type hand grip, controls rotation in any direction.

The HHMU is a handgrip unit with a pair of thrusters that pull the astronaut forward, a single thruster that pushes him backwards, and thruster controls. To propel himself, the operator points the unit in the appropriate direction and triggers the nozzle(s) required for the direction in which he wishes to travel.

Foot Controlled Maneuvering Unit (T020)

This experiment will evaluate an astronaut maneuvering device that does not require use of the astronaut's hands. Both the ASMU and the HHMU (Experiment M509) required the astronaut to use his hands to control the unit. The foot controlled maneuvering unit (FCMU) is a foot operated propulsion device that is straddled by the operator very much as he would if riding a bicycle. The unit is propelled by high pressure nitrogen contained in the detachable propellant tank used in the M509 experiment (Fig. 26).

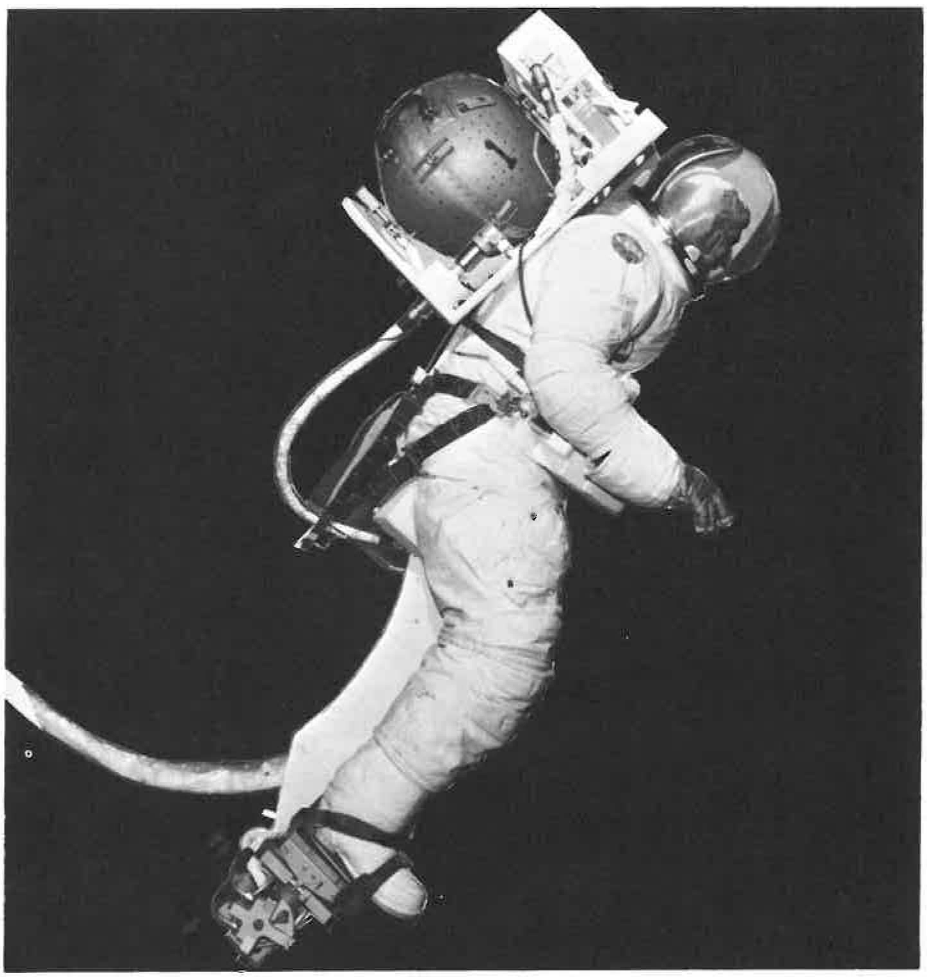


Fig. 26 Foot Controlled Maneuvering Unit

Crew Activities in Maintenance (M516)

The primary objective of this experiment is to evaluate Skylab spacecraft designs and crew proficiency in conjunction with the performance of work under long duration zero gravity conditions.

Previous evaluations indicated that man in space can do many of the activities that he accomplishes on Earth. Considerable data have been accumulated concerning inflight crew performance in control and display operations, navigation, decision making, etc. However, very limited data have been provided concerning man's capabilities to perform physical work in the space environment. Data concerning the crew's ability to use tools to assemble and disassemble equipment (manual dexterity), to maneuver inside the spacecraft (locomotion), and to transfer and handle masses of various sizes (mass handling and transfer) have been limited by relatively small-volume space vehicles and short-duration missions.

Skylab will be the first NASA manned program intended for long term living and working in the space environment. Skylab onboard systems have been designed to optimize the man/machine interfaces and, thereby, maximize work relationships. Due to the paucity of relevant data from previous spaceflights, design decisions concerning crew work capabilities in zero-g require validation. Validation of the Skylab man/machine interface design criteria will serve as a basis for establishing design criteria for future manned space systems.

Crew/Vehicle Disturbances (T013)

The objective of this experiment is to determine the effect of the crew's activities within the spacecraft on the Skylab vehicle's pointing stability.

Many Earth pointing and astronomy experiments in future manned space programs will require pointing accuracies as rigorous as fractions of a second of arc. One of the most significant hindrances to achieving this accuracy may well be the movement of the astronauts operating the spacecraft. Adequate design of the pointing control systems for these future vehicles demands accurate knowledge of these effects.

In this experiment the forces exerted on the spacecraft by specific astronaut body and limb movements will be precisely measured. A limb motion sensor, attached to a suit, will measure the relative motions of the body, upper arm, lower arm, and upper and lower leg. The astronaut performing the experiment will stand on a device that measures the force exerted on the Skylab structure by his activities.

The limb movements and forces will be recorded on tape, and the activity will be photographed on motion picture film.

Space Navigation Measurements (T002)

This experiment will investigate the effects of long duration space flight on a navigator's ability to make space navigation measurements using hand-held instruments.

Previous data, obtained from ground simulation, aircraft flights, and Gemini flights indicate that man can make accurate navigation measurements using hand-held instruments, as well in space as on land or sea. This means that it is feasible for astronauts to navigate in space with simple instruments and without a computer. The intent of this experiment is to determine whether the long duration mission affects this ability.

Using a sextant, sightings will be made of selected stars to determine position. Sightings on the Earth's horizon will be made using a stadiometer to determine spacecraft altitude.

Radiation in Spacecraft (D008)

The purpose of the experiment is to make radiation-dose measurements in Earth orbit. Such measurements are of importance in assessing the quality of dosimetry instrumentation for space application, in evaluating various analytical procedures that predict the radiation dose received in Earth orbit, and in studying the biological reaction of man to such radiations.

The major source of radiation in Earth orbit arises in the South Atlantic Anomaly, a region where, because of the particular shape of the Earth's magnetic field, the Van Allen radiation belts are unusually close to Earth. In other places, the radiation belts are relatively weak below an altitude of, say, 250 nautical miles.

In the orbit chosen for Skylab, significant radiation doses are experienced only when the spacecraft passes through the South Atlantic Anomaly. There is, however, a continuous background of radiation from cosmic ray sources and it is possible that major solar flares occurring during a mission can generate high energy protons and alpha particles that will contribute to the radiation environment. All of these effects will be recorded by this experiment.

Inflight Aerosol Analysis (T003)

The objective of this experiment is to measure the size, concentration, and composition of the minute particles present in the atmosphere inside Skylab. The information obtained will be used not only as a measure of the atmospheric quality in Skylab, but as a data source in analysis of other Skylab phenomena. Sources of astronaut discomfort, either respiratory or skin, may be related to aerosol buildup; system performance anomalies may be resolved using this data; and, lastly, the data can be used in the design of future spacecraft and equipment.

Measurements will be taken periodically at selected locations and the filters used in each measurement will be returned to Earth for analysis.

Coronagraph Contamination Measurements (T025)

The primary objective of this experiment is to study particles in the atmosphere surrounding the spacecraft and the change (size, quantity and distribution) in these particles caused by thruster firing, water dump, etc. A secondary objective is to photograph the solar corona to find out if the contamination degrades the ability to see this faint illumination.

Apollo astronauts have visually reported "fireflies," or ice crystals, during and up to 30 minutes or more after water and urine dumps. Photographic records were made with a 16 mm movie camera on Apollo 9 from which some scientific information was gathered on the particle velocities and sizes. Ground-based telescopes have also photographed water dumps and other releases from SIV-B Saturn rocket stages. More quantitative information is needed, however, on the atmosphere that Skylab will create around itself.

Contamination Measurement (T027)

The objective of this experiment is to study the deposition of contamination on Skylab's optical surfaces and the brightness of the contamination when illuminated by the Sun.

Deposition of contamination on windows was observed on many Gemini and Apollo flights where it interfered with star sighting and lunar surface photography experiments.

Sources of this contamination are thought to be the exhaust from thruster firings and evaporations from window seals. However, no detailed postflight analysis has been possible because of effects of reentry, which either disperses the contamination or covers it with a layer of reentry contaminants.

This experiment will collect samples of contaminants on specially prepared surfaces. These surfaces will be exposed to the contamination surrounding Skylab by extending them into space on a boom through an airlock on the side of the OWS. Following exposure, the samples will be recovered and stored for return to Earth for analysis under controlled conditions.

In addition, photometer measurements will be made of the brightness of the coat of contaminants on selected windows, when illuminated by the Sun. This data can be used in calibrating the quality of observations made with ATM telescopes and other optical devices in Skylab.

Thermal Control Coatings (M415)

This experiment will determine the relative effects of the prelaunch, launch, and space environments on the thermal absorption and emission characteristics of various coatings commonly used for passive thermal control.

An easy way to control spacecraft temperatures is by applying coatings with thermal properties matched to the space environment and to heat rejection/absorption requirements. Unfortunately, the environments to which these coatings are exposed before and during flight often alter their properties even to the point of making them ineffective. In the past, no precise measurement of the extent of this degradation has been possible. In this experiment, samples of three different coatings will be exposed to some, or all, of the environments encountered and their thermal properties measured by temperature sensors. The data will be telemetered to the ground.

Thermal Control Coatings (D024)

This experiment has the objective of exposing thermal coating material samples to the space environment only (excluding prelaunch and launch) in order to determine the effects of that environment on these coatings and the validity of ground-based simulations of on-orbit environmental effects.

Lack of precise knowledge of the effect of the space environment on thermal coatings has lead, in earlier space programs, to over-design of thermal control components such as radiators. This experiment will provide the first opportunity to expose such coatings, for long periods, to the space environment and to return them for analysis without adverse effects from the reentry environment.

Materials Processing in Space (M512)

This experiment is fundamental research into the effects of zero gravity on molten metal processing.

The tasks that make up this experiment all involve the melting of materials by the application of heat. On Earth, temperature differences cause density differences which, under the influence of gravity, result in convection. This may, or may not, be a hindrance on Earth; however, in zero gravity it definitely is not a problem.

Another effect of gravity that space processing can avoid is the separation of different density materials in the preparation of composites. Certain materials of superior characteristics could be formed if a uniform or other preferred mixture of substances of different density could be attained. On Earth, the desired embedded fibers or particles either float or settle, but in space this should not occur.

Five tasks are contained in this experiment.

- Metals melting—Examine the molten metal flow characteristics of various metal alloys.

- Sphere forming—Fabricate spherical shapes by taking advantage of the virtual absence of gravity.

- Exothermic heating—Develop a stainless steel tube joining technique for assembly and repair in space, to evaluate the flow and capillary action of molten braze material and to demonstrate the feasibility of exothermic reaction in space.

- Composite casting—Fabricate three composite materials in space by nondirectional solidification of aluminum alloys and compare with specimens cast on Earth to identify improvements, if any, of the metallurgical structure.

- Single crystals—Grow unique single crystals of gallium arsenide.

Zero Gravity Flammability (M479)

The purpose of this experiment is to obtain photographic data of various combustible materials ignited under controlled conditions in a zero gravity environment to determine their flame propagation, flashover, and extinguishment characteristics.

Previous studies of flame propagation under conditions of zero gravity were conducted in aircraft. Self-extinguishment was observed but the flame reappeared when convection resumed at the end of weightlessness. Longer test times are required so that more information can be obtained.

The objectives of experiment M479 are to ignite various materials in a special combustion chamber, in the presence of Skylab cabin atmosphere gas, to determine the following data.

- The extent of surface flame propagation, flashover to adjacent materials, etc.

- Rates of surface and bulk flame propagation under zero convection.

- Self-extinguishment possibilities as a function of fuel composition and geometry.

- Behavior during extinguishment by vacuum or water spray.

This experiment will be conducted in the M512 materials processing facility.

Precision Optical Tracking (T018)

The objective of this experiment is to demonstrate the ability of a laser tracking system to accurately measure the position and motion of a space vehicle booster during the early launch phase.

The experiment hardware consists of a pair of corner reflectors mounted on the instrument unit of the Saturn IB launch vehicles, and a ground-based continuous beam gas laser located three kilometers from the launch site. The laser illuminates the launch vehicle with a one-meter diameter spot of light and automatically tracks the vehicle for the first 50 seconds of flight, generating range and direction data and the rates at which they change.

Sleep Monitoring (M133)

The objective of this experiment is to establish the feasibility of near-real-time monitoring of the quantity and quality of an astronaut's sleep patterns during prolonged space flight. This will be done by automated onboard monitoring, recording, and analysis of EEG (electroencephalographic, i.e., brain waves) and EOG (electro-oculographic, i.e., eye movement) data, with the results telemetered to Earth. M133 embodies significant advances over the methods used in NASA's first attempt to evaluate EEG patterns during Gemini 7. These include the use of caps to eliminate the need to pre-attach electrodes and the capability for near-real-time monitoring and status assessment.

Real-time monitoring of sleep information will be available in the Mission Control Center. It will be possible to show the astronaut's sleep state and to plot a continuing sleep profile. Any alteration in sleep quantity or quality may be readily detected and evaluated.

Time-and-Motion Study (M151)

This experiment will determine, through analysis of film, the effectiveness of crewmen performing inflight tasks compared with their effectiveness in performing the same tasks during preflight zero gravity simulations.

It is believed that these inflight tasks will generally take more time than they did on Earth and be done less efficiently, depending upon the nature of the task. Zero gravity and the other variables of spaceflight such as a 5 psia environment are expected to affect not only the time required but the motion patterns required to perform the tasks. Analysis of data from this experiment will:

- Provide information on how man performs specific tasks in space and the variables affecting time and motion patterns required to perform these tasks (pertinent to procedures, schedules, methods, tasks, and equipment for future missions);

- Provide data on the effectiveness of restraint systems and the energy cost of astronaut movements;

- Provide insight to any possible degradation of skill or learning caused by extended space flight;

- Help define the training time and level of training that a crewman requires to perform inflight tasks efficiently;

- Aid in definition of the time and resource requirements for ground-based training (including neutral buoyancy and zero gravity training flights for specific astronaut activities);

- Help in defining the proper interface of man and equipment in zero-gravity.

Motion picture film will provide a permanent record to allow investigators to study time and motion patterns.

Mass Measurement (M074 and M172)

Two of the experiments described in the biomedical science section also apply to the space applications series of experiments. These experiments, Specimen Mass Measurement (M074) and Body Mass Measurement (M172), measure the effectiveness of mass measurement devices in space.

V. Glossary

AM	Airlock Module
APCS	Attitude and Pointing Control System
ASMU	Automatically Stabilized Maneuvering Unit
ATM	Apollo Telescope Mount
ATMDC	Apollo Telescope Mount Digital Computer
β	Minimum Angle between the Earth-Sun Line and the Vehicle Orbital Plane
BMMD	Body Mass Measurement Device
CBRM	Charger/Battery/Regulator Modules
CM	Command Module
CMC	Command Module Computer
CMG	Control Moment Gyro
CMGS	Control Moment Gyro Subsystem
COAS	Crewman Optical Alignment Sight
CS	Crew Station
CSM	Command and Service Module
DA	Deployment Assembly
DAC	Data Acquisition Camera
DAP	Digital Autopilot
DCS	Digital Command System
DNA	Deoxyribonucleic Acid
DSKY	Display Keyboard
DT	Delayed Time
ECS	Environmental Control System
EEG	Electroencephalographic
EOG	Electro-oculographic
EPC	Experiment Pointing Control
EPCS	Experiment Pointing Control Subsystem
EPS	Electrical Power System
EREP	Earth Resources Experiment Package
ESS	Experiment Support System
EVA	Extravehicular Activity
FAS	Fixed Airlock Shroud

FCMU	Foot Controlled Maneuvering Unit
FM	Frequency Modulation
FMS	Force Measuring System
FMSC	Film Magazine Stowage Container
FMU	Force Measuring Unit
FOV	Field of View
FSS	Fine Sun Sensor
GMT	Greenwich Mean Time
GNCS	Guidance Navigation and Control System
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
HCO	Harvard College Observatory
HHMU	Hand Held Maneuvering Unit
HPN	Heavy Primary Nuclei
HSS	Habitability Support System
IMC	Image Motion Control
IMU	Inertial Measurement Unit
IU	Instrument Unit
IVA	Intravehicular Activity
KSC	Kennedy Space Center
LBNP	Lower Body Negative Pressure
LBNPD	Lower Body Negative Pressure Device
LIMS	Limb Motion Sensor
LO	Liftoff
LOS	Loss of Signal, also Line of Sight
LSU	Life Support Umbilical
LV	Launch Vehicle
MCC	Mission Control Center
MCSS	Microscopic Camera Subsystem
MDA	Multiple Docking Adapter
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSS	Motion Sickness Susceptibility
MU	Maneuvering Unit

NASA	National Aeronautics and Space Administration
NM	Nautical Mile
NRL	Naval Research Laboratory
OGI	Oculogyral Illusion
OMSF	Office of Manned Space Flight
OTG	Otolith Test Goggles
OWS	Orbital Workshop
PCM	Pulse Code Modulation
PI	Principal Investigator
PMT	Photomultiplier Tube
POTS	Precision Optical Tracking System
PS	Payload Shroud
PSS	Propellant Supply Subsystem
RBC	Red Blood Cell
RCS	Reaction Control System
RF	Radio Frequency
RLC	Rotating Litter Chair
RNA	Ribonucleic Acid
RMS	Root Mean Square
RPM	Revolutions per Minute, also Roll Positioning Mechanism
SAA	South Atlantic Anomaly
SAL	Scientific Airlock
SAS	Solar Array System
S/C	Spacecraft
SL	Skylab
SLA	Spacecraft Lunar Module Adapter
SM	Service Module
SMMD	Specimen Mass Measurement Device
sps	Samples per Second
SPS	Service Propulsion System
STS	Structural Transition Section
SWS	Saturn Workshop
SXT	Sextant
TACS	Thruster Attitude Control Subsystem
TCS	Thermal Control System

TM	Telemetry
TR	Tape Recorder
TV	Television
UV	Ultraviolet
VCG	Vectorcardiogram
VHF	Very High Frequency
XUV	Extreme Ultraviolet

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